# THE INSTITUTION OF PETROLEUM TECHNOLOGISTS.

## ANNUAL REPORT OF THE COUNCIL FOR 1924.

The Council has pleasure in presenting their Annual Report, together with the Accounts, for the year ended December 31st, 1924.

During the year there was a net increase of 73 Members, the state of membership at December 31st, 1924, as compared with 1923, being as follows :—

| | 1923. | 1924. |
|---|---|---|
| Honorary Members .. .. | 9 | 9 |
| Members .. .. .. | 340 | 382 |
| Associate Members .. .. | 165 | 182 |
| Students .. .. .. .. | 110 | 118 |
| Associates .. .. .. .. | 32 | 38 |
| Total .. .. .. | 656 | 729 |

At that date 28 prospective Members had been nominated, in addition to 14 who had been elected but had not then taken up their membership.

The Council, in presenting the Accounts for the year ended December 31st, 1924, are pleased to state that the Balance Sheet shows a satisfactory financial position. The activities of the Institution have materially increased, and in addition to incurring the expense of two additional Journals issued during the year, the cost of which is borne in the present Accounts, financial co-operation was accorded to allied Scientific Bodies in connection with Special Subjects of Technological interest.

The Report of the Standardisation Committee, under the title of "Standard Methods of Testing Petroleum and Its Products," was published during the year, and the appreciation of the value of this work has been shown by the large number of applications for copies which have been received.

The Institution published, in conjunction with the Institution of Automobile Engineers, a Report of the Empire Motor Fuels Committee, and this is issued to Members at a nominal charge to cover postage.

The Institution was one of the Convening Bodies of the Empire Mining and Metallurgical Congress, which was opened at the British Empire Exhibition, Wembley, on June 3rd, 1924, by the President of the Congress, the late Lord Long of Wraxall, and was responsible for Section B, Petroleum. The papers read before this Section of the Congress were published in a special issue of the Journal, No. 44, viz. :—

"THE ECONOMICS OF THE OIL INDUSTRY," by Sir Robert Waley Cohen.

"PETROLEUM GEOLOGY," by T. Dewhurst.

"THE EVOLUTION OF OIL-WELL DRILLING METHODS," by A. Beeby Thompson.

"PETROLEUM ENGINEERING," by C. Dalley.

"CRUDE OILS OF THE EMPIRE," by A. E. Dunstan and James Kewley.

"THE REFINING OF OIL-SHALE," by Edwin M. Bailey.

"OIL TRANSPORT: THE OIL TANK SHIP," by H. Barringer.

"BULK DISTRIBUTION OF OIL: DEPOTS AND STORAGES," by Sir Frederick W. Black.

The Institution is represented on :—

The British Engineering Standards Association.

The Imperial Mineral Resources Bureau.

The Fuel Economy Committee.

The British Association for the Advancement of Science.

The Committee of Birmingham University, which is responsible for the Education of Petroleum Technologists, and

The American Society for Testing Materials.

The Institution was also represented on the occasion of the Centenary Celebration of the Founding of the Franklin Institute and the Inauguration Exercises of the Bartol Research Foundation, which took place in Philadelphia in September, 1924; on the Chemical Section of the British Empire Exhibition, Wembley, 1924; and at the International Petroleum Exposition and Congress, which was held at Tulsa, Oklahoma, in October, 1924.

During the year the following papers were read before the Institution and published, together with the discussions thereon, in the Journal :—

At the Seventy-fifth General Meeting: "THE CRUDE OIL OF SARAWAK," by James Kewley, and "THE CRUDE OIL OF MAIDAN-I-NAFTUN," by A. E. Dunstan.

At the Seventy-sixth General Meeting: "ELECTRICITY APPLIED TO THE WINNING OF CRUDE PETROLEUM, WITH SPECIAL REFERENCE TO THE YENANGYOUNG FIELD, BURMAH," by C. H. McCarthy-Jones.

At the Eleventh Annual General Meeting: "THE ENGINEER IN RELATION TO THE PETROLEUM INDUSTRY," by H. Barringer (Presidential Address).

At the Seventy-seventh General Meeting: "THE CRUDE OILS OF BURMAH AND ASSAM," by W. J. Wilson.

At the Seventy-eighth General Meeting: "THE GEOLOGY AND OIL MEASURES OF SOUTH-WEST PERSIA," by R. K. Richardson.

At the Seventy-ninth General Meeting: "RECENT DEVELOPMENT IN THE ART OF CRACKING," by A. E. Dunstan and Robert Pitkethly.

At the Eightieth General Meeting: "THE OILFIELDS OF ARGENTINA," by Campbell M. Hunter.

At the Eighty-first General Meeting: "FUEL OIL RESOURCES OF THE FUTURE," by Alfred W. Nash and H. G. Shatwell, and "THE SOMERSET OIL-SHALES," by H. G. Shatwell, Alfred W. Nash and J. Ivon Graham.

The total attendance at the seven General Meetings held during the year amounted to 805, the average for each meeting being 80 Members and 35 Visitors.

In addition to the papers mentioned above, a number of others have been published in the Journal, and No. 45 contained articles dealing with the progress made during 1923 in various phases of the Petroleum Industry as follows:—

"HEAVY DISTILLATES," by H. Moore; "LUBRICANTS AND LUBRICATION," by R. W. L. Clarke; "SPECIAL PRODUCTS," by F. G. P. Remfry; "CHEMISTRY," by F. B. Thole; "ANALYSIS AND TESTING," by S. Bowman; "CRACKING," by R. Pitkethly and A. E. Dunstan; "REFINING AND REFINERIES," by J. McConnell Sanders; "AGWI REFINERY," by J. McConnell Sanders; "SKEWEN REFINERY," by A. M. O'Brien; "SCOTTISH OIL INDUSTRY"; "THE BURMAH OIL COMPANY," by John Gillespie; "OIL SEPARATORS," by H. Barringer; "PETROLEUM GEOLOGY," by J. N. Montgomerie; "RUMANIA," by C. Leu; "HYDROGENATION," by H. I. Waterman and J. N. J. Perquin; "THE INSTITUTION," by G. Sell; "STATISTICS," by Arthur W. Eastlake, and "BIBLIOGRAPHY."

It is proposed to devote one issue of the Journal annually to such reports to cover, as far as possible, every branch of the Industry and all countries producing petroleum. Members are invited to

furnish communications on any special subject with which they are familiar.

Sir Thomas Holland, K.C.S.I., K.C.I.E., D.Sc., F.R.S., has been unanimously elected as President for the ensuing Session, and the following Vice-Presidents have been unanimously re-elected :—The Right Hon. Viscount Cowdray of Cowdray, Sir John Cargill, Mr. Alfred C. Adams, Mr. Arthur W. Eastlake, and Mr. Robert Redwood. In addition, Mr. Alexander Duckham has been unanimously elected a Vice-President for the ensuing Session.

The Boverton Redwood Medal, presented by Mr. Alexander Duckham in commemoration of the late Sir Boverton Redwood was made retrospective to 1919, and for the Sessions 1919-1921 was awarded to M. Paul de Chambrier for his paper, "The Working of Petroleum by Means of 'Shafts' and 'Galleries,'" which was read on February 15th, 1921. It is hoped to present the Medal to M. de Chambrier at the Seventh Annual Dinner on March 17th. For the Sessions 1921-1923 no award was made as it was considered that there had been no paper of outstanding merit during that period.

The Students' Section has continued its activities during the year, and the Honorary Secretaries of the London and Birmingham Branches report that they have held eight and six meetings respectively, all of which were well attended.

The Students' Medal and Prize for the 1923-1924 Session was awarded to Lieut. J. H. Blakiston for his paper, "The Rumanian Oilfields," which was published in Journal No. 46. The award of the Institution Scholarships was made to Mr. E. Clark at the Royal School of Mines, and Mr. G. Cotton at Birmingham University.

In connection with the Students' Section the Council desire to record their grateful thanks to the Right Hon. Viscount Cowdray of Cowdray for his generosity in presenting the sum of £100 to be used for the encouragement of Students.

The attendance of Members and Guests at the Sixth Annual Dinner was over 200.

The Council deeply regret that they have to announce the deaths of eight Members, namely :—Sir George Beilby, Messrs. G. E. Brown, H. T. Burls, P. B. M. Furnell, C. P. Hale, Professor R. R. Thompson, J. M. White and G. A. Galbraith.

The Council desire to place on record their thanks for, and appreciation of, the courtesies extended to the Institution by the Royal Society of Arts for allowing the use of their house for meetings, and by the Chemical Industry Club for permitting the Members of the Dinner Club to dine at, and have the use of, their premises.

The Council wish to express their appreciation and thanks for the valuable services rendered by Sir William Plender, Bart., G.B.E., Honorary Treasurer; Messrs. Ashurst, Morris, Crisp and Company, Honorary Solicitors; Messrs. Price, Waterhouse and Company, Auditors; Dr. A. E. Dunstan, Honorary Editor, and his Assistant, Mr. George Sell; and the Secretary, Commander R. E. Stokes-Rees, R.N., and his staff.

The Auditors retire and offer themselves for re-election.

By order of the Council,

ARTHUR W. EASTLAKE,
*Honorary Secretary.*

## REVENUE ACCOUNT for the Year ended 31st December, 1924.

| Dr. | £ | s. | d. |
|---|---|---|---|
| To Salaries | 797 | 17 | 8 |
| „ Rent, Rates, etc. | 461 | 18 | 5 |
| „ Printing and Stationery | 120 | 15 | 1 |
| „ Postage | 151 | 13 | 1 |
| „ Hire of Hall for Meetings and Expenses of Meetings | 261 | 16 | 1 |
| „ Abstracts and Reviews | 210 | 7 | 7 |
| „ Standardization Committee | 64 | 9 | 6 |
| „ Journals | 693 | 10 | 3 |
| „ Empire Motor Fuels Committee Report | 97 | 17 | 7 |
| „ Income Tax on Interest and Dividends paid without Deduction | 27 | 1 | 1 |
| „ Sundry Expenses | 186 | 13 | 8 |
| „ Depreciation of Office and Library Furniture | 26 | 8 | 11 |
| | £3100 | 8 | 11 |

| Cr. | £ | s. | d. | £ | s. | d. |
|---|---|---|---|---|---|---|
| By Subscriptions— | | | | | | |
| Members | 1743 | 10 | 6 | | | |
| Special | 875 | 0 | 0 | | | |
| | | | | 2618 | 10 | 6 |
| „ Interest and Dividends | | | | 96 | 0 | 6 |
| „ Sale of Books | | | | 18 | 6 | 3 |
| „ Balance carried to Balance Sheet | | | | 367 | 11 | 8 |
| | | | | £3100 | 8 | 11 |

## STUDENTS' PRIZE AND SCHOLARSHIP FUND.

| 1924. | | £ | s. | d. |
|---|---|---|---|---|
| 31st Dec. | To Scholarships granted:— | | | |
| | Royal School of Mines | 40 | 0 | 0 |
| | Birmingham University | 40 | 0 | 0 |
| | „ Balance | 20 | 0 | 0 |
| | | £100 | 0 | 0 |

| 1924. | | £ | s. | d. |
|---|---|---|---|---|
| 1st Jan. | By Balance brought forward | 100 | 0 | 0 |
| | | £100 | 0 | 0 |

## STUDENTS' SECTION FUND.

| 1924. | | £ s. d. |
|---|---|---|
| 31st Dec. | To Expenses for the Year .. .. .. | 17 13 0 |
| | „ Balance .. .. .. .. .. .. | 82 7 0 |
| | | £100 0 0 |

| 1924. | | £ s. d. |
|---|---|---|
| 29th Apr. | By Amount received .. .. .. .. | 100 0 0 |
| | | £100 0 0 |

## BALANCE SHEET as at 31st December, 1924.

### LIABILITIES.

| | £ s. d. | £ s. d. | £ s. d. |
|---|---|---|---|
| To Capital of the Institution, under Bye-Law Section 6, para. 14, viz. :— | | | |
| Life Membership Fund, as per last Account .. .. .. | 413 0 0 | | |
| Entrance Fees— | | | |
| Per last Account .. .. | 836 16 0 | | |
| Additions during year .. .. | 139 13 0 | | |
| | | 976 9 0 | |
| Donations per last Account .. | 300 0 0 | | |
| Additions during year .. .. | 26 5 0 | | |
| | | 326 5 0 | |
| | | | 1715 14 0 |
| „ Students' Prize and Scholarship Fund | | | 20 0 0 |
| „ Students' Section Fund .. | | | 82 7 0 |
| „ Subscriptions paid in Advance | | | 186 18 0 |
| „ Sundry Creditors .. .. | | | 379 16 8 |
| „ Revenue Account— | | | |
| Balance, 31st December, 1924 | | 1755 18 2 | |
| Less : Arrears of 1923 Subscriptions written off .. .. | | 21 0 0 | |
| | | 1734 18 2 | |
| Less : Balance for year as per Revenue Account, 1924 .. | | 367 11 8 | |
| | | | 1367 6 6 |
| | | | £3752 2 2 |

## ASSETS.

| | £ s. d. | £ s. d. |
|---|---|---|
| By INVESTMENTS, AT COST— | | |
| £664 6 6 London County 3% Consolidated Stock .. .. .. .. | 481 10 6 | |
| £925 5% War Loan, 1929–47 .. .. .. | 862 18 4 | |
| £50 0 0 National War Bond, 5% 1927 .. | 50 0 0 | |
| £150 0 0 Birmingham Corporation 6% Stock | 146 16 0 | |
| | | 1541 4 10 |
| *Note.*—Market price of above Investments at 31st December, 1924, was £1590 12s. 4d. | | |
| „ OFFICE AND LIBRARY FURNITURE (excluding presentations)— | | |
| As per last Account .. .. .. .. | 504 16 9 | |
| Additions during the year .. .. .. | 24 1 4 | |
| | 528 18 1 | |
| *Less:* Depreciation at 5% .. .. .. | 26 8 11 | |
| | | 502 9 2 |
| „ LIBRARY (BOOKS) (excluding presentations)— | | |
| As per last Account .. .. .. .. | 125 2 0 | |
| Additions during year .. .. .. .. | 18 9 10 | |
| | | 143 11 10 |
| „ SUBSCRIPTIONS (1924) OUTSTANDING AT DATE AND CONSIDERED COLLECTIBLE .. .. | | 71 18 6 |
| „ SUNDRY DEBTORS AND PAYMENTS IN ADVANCE | | 107 3 10 |
| „ CASH ON DEPOSIT .. .. .. .. .. | | 1143 19 8 |
| „ CASH AT BANK AND IN HAND .. .. .. | | 241 14 4 |
| | | £3752 2 2 |

We have examined the above Balance Sheet with the books of the Institution, and having obtained all the information and explanations we have required, we are of the opinion that such Balance Sheet is properly drawn up so as to exhibit a true and correct view of the state of the Institution's affairs, according to the best of our information and the explanations given to us and as shown by the books of the Institution.

3, FREDERICK'S PLACE,
OLD JEWRY, E.C. 2. PRICE, WATERHOUSE & CO.

28*th January*, 1925.

## THE INSTITUTION OF PETROLEUM TECHNOLOGISTS.

The Twelfth Annual General Meeting of the Institution was held in the House of the Royal Society of Arts, John Street, Adelphi, London, W.C., on Tuesday evening, March 10, 1925, Mr. Herbert Barringer, M.Inst.C.E., M.I.Mech.E., M.I.N.A., M.Inst.Mar.Eng., President, occupying the chair.

**The President,** at the opening of the meeting, announced that the Council had decided to award two scholarships of £40 each for the current year, one to a student of the Royal School of Mines and the other to a student of the University of Birmingham.

**The Secretary** having read the notice convening the meeting, the Minutes of the Eleventh Annual General Meeting were read and signed as correct.

The list of members elected during the year was produced and placed on the table for inspection.

**The President** said that as the Annual Report had been circulated he proposed to take it as read and formally moved its adoption.

**Mr. James Kewley** seconded the motion.

**The Secretary** read the following reports from the London and Birmingham Branches of the Students' Section :—

London Branch.—A successful year's work has been completed since the first Annual Report, March, 1924.

The following meetings were held during the 1924 session :—

March.—General Discussion on the Economic Situation in the Petroleum Industry.

April.—Fuller's Earth. A. Rauch.

May.—Percussion Systems of Drilling. H. G. Austin.

Of the eight committee men elected at the last Annual General Meeting, five were compelled to resign, as they were taking up positions abroad, these being Messrs. Austin, Chairman and Honorary Secretary, Morrison, Mendelsohn, Miskin and Stewart, leaving Messrs. Owen, first vice-chairman, Garlick, second vice-chairman, and Davies, to form the nucleus of a new committee for the 1924–25 session. As a result, Mr. Owen became Chairman, Mr. Garlick Vice-Chairman, while Mr. Kay took the position of Honorary Secretary, with Messrs. Davies and Clark also on the Committee, leaving three vacancies.

Four papers have been read this session :—

October.—Chemistry of Petroleum. H. S. Garlick.

November.—Oilfields of Poland. T. G. B. Davies.

December.—Some Legal Aspects of Petroleum. J. B. Kay.
January.—Organic Theories of Oil Origin. E. Clark.

Not only are the papers read at the Student Meetings eligible for the Medal and Prize of the Institution, but also any paper which a Student Member cares to send to the Institution on any subject connected with petroleum technology. The first award during the 1923–24 session was made to Lieutenant J. H. Blakiston, R.N.R., of the Birmingham Branch, for his paper entitled "The Oilfields of Rumania."

Mr. E. Clark, of the Royal School of Mines, and Mr. G. Cotton of Birmingham University, gained the Institution's scholarships for 1924, which are awarded annually, one to each college to a third year student taking the petroleum technology course, who is also a Student Member of the Institution.

During the 1924 session many attempts were made for Saturday excursions by Mr. Miskin, Excursion Secretary, but unfortunately nothing materialised. This session, one excursion has been made, on Saturday, October 18, 1924. The Student Members were invited by Messrs. Vickers, Ltd., to a demonstration of rotary drilling at the firm's electrically driven drilling rig at the British Empire Exhibition. The operations of adding drill stem and changing bits were shown, after which the party were entertained to tea at Messrs. Vickers' stand in the Palace of Engineering. The attendance was disappointingly small.

The First Annual Report stated that there were over 110 Student Members on the Roll of the Institution. It should be pointed out that this number was made up as follows :—

| | | | |
|---|---|---|---|
| Resident in London | .. .. .. .. | 35 | 115 |
| ,, in Country | .. .. .. .. | 25 | |
| ,, Abroad | .. .. .. .. | 55 | |

Hence, an average attendance of 15—20 is not distressing. The membership is increasing. The resignation of Mr. A. P. Crump, necessitated by a new position, is accepted with regret.

Negotiations are in hand for the use of the Institution's library after 5 p.m.

The Committee wish to thank those senior members of the Institution who have attended the Student meetings : the support and helpful criticism given has been most heartily appreciated. Particularly does this refer to those members who have consistently aided us in this way.

(Signed) J. B. KAY, *Hon. Sec.*
(Countersigned) H. BARRINGER, *President.*

February 17, 1925.

BIRMINGHAM BRANCH.—A Committee Meeting was held on October 13, 1924, when Mr. G. C. K. Dunsterville was elected Chairman and Mr. W. Harrison Vice-Chairman. Prof. A. W. Nash, B.Sc., M.I.Mech.E., tendered his resignation as Honorary Secretary, which was reluctantly accepted, and Mr. Launcelot P. Timmins, F.G.S., was elected in his place.

The following meetings have taken place so far, and have all been well attended both by members and visitors.

*November* 18, 1924.—A paper was read by Dr. Dunstan, D.Sc., F.I.C., F.C.S. (Member of Council) entitled "The Refining of a Typical Crude Oil."

*December* 9, 1924.—A paper was read by Mr. W. J. Wigney, of the National Supply Corporation, on "Recent Developments in Oilfield Equipment." Many interesting slides were shown.

*January* 27, 1925.—A paper was read by Mr. G. Cotton (Student), entitled "Fire Problems on Oilfields and Refineries."

*February* 17, 1925.—A paper was read by Mr. H. G. Shatwell, M.Sc. (Vic.), A.I.C., entitled "Hydrogenation by the Bergius Process."

*February* 26, 1925.—A very interesting and instructive visit was paid to Messrs. J. and E. Wright, Ltd., Universe Rope Works, Birmingham, when the various processes employed in the manufacture of steel and manilla drilling cables were inspected. The party was conducted by Mr. Terry, who explained the details of the various processes, and a number of tension, torsion and Brinell tests were carried out for the members' benefit.

Arrangements are being made for visiting some chilled-shot core-drilling operations in this neighbourhood and two more papers are to be read by members on March 17 and May 19, respectively.

The membership has increased and great keenness is displayed in the Society's welfare.

(Signed) LAUNCELOT P. TIMMINS, *Hon. Sec.*
(Countersigned) H. BARRINGER, *President.*

**The President** said he was sure the members would agree with him that the reports of the Students' Branches which had just been read were most encouraging. The 118 students were doing very good work, and in particular some excellent papers were being received from them.

The motion for the adoption of the Report was then put and carried.

**The President** then formally moved the adoption of the Balance Sheet attached to the Annual Report.

**The Secretary** read the Auditors' Certificate attached to the Balance Sheet.

**Mr. Alfred C. Adams** (Chairman of the Finance Committee), in seconding the motion, said that for several years past it had been his privilege to speak in regard to the accounts. He thought all the members would agree with him that the accounts were in a very simple form and did not require much explanation. As, however, the present accounts were presented in a slightly different form from those of previous years, he desired to say a few words upon them. It would be noticed first of all that in 1924 the Institution spent rather more than its income. He only mentioned that fact because it was something that had not occurred before. But naturally there was nothing unusual or remarkable in that being the case, since it would be realised that the Institution did not exist for the purpose of making profits. As a matter of fact it did not do so. In pursuing its objects the Institution had in previous years received more income than it actually spent in the year. That situation had produced a credit balance which for several years past had been carried forward and accumulated, as the Balance Sheet indicated. Those funds were in reserve until the Council needed, for the purposes of the Institution, to spend some of that money, and it naturally drew upon them if the income for the year was not sufficient for its purposes. The income of the Institution was derived from subscriptions, from interest and from dividends on invested funds. It either spent the whole of its yearly income or it did not, and in 1924 it spent some of the money which it had not spent in earlier years. The year 1924 was in many respects one of considerable activity. Participation in such movements as the International Mining and Metallurgical Congress produced a number of very valuable papers, but involved an increase in the number of Journals issued. As the members were aware, seven Journals were published in 1924 against six in 1923. There were various other movements which caused certain calls upon the Institution's funds, the result of which was indicated in the accounts —namely, that £367 11s. 8d. had been spent out of the accumulated funds, which consisted of the unspent money of previous years. Turning to the Balance Sheet, it would be noticed that the capital of the Institution now amounted to £1,715 14s. That represented the amount of Entrance Fees, Life Membership Subscriptions and Donations, which, by the Constitution, had to be invested. Turning to the item of investments on the opposite side of the accounts, it would be seen that about £184 was in hand for investment, and as nearly as possible that amount had been invested since the close of last year. The amount against Students' Scholarships represented funds in the Students' Section account and consisted of sums in hand for those particular purposes. Sundry Creditors represented accounts for printing the Journal and various ordinary business accounts unpaid at the 31st December, but which had

since been discharged in the ordinary course. On the other side, the items representing library, office furniture and books were naturally below their actual value owing to the very large number of valuable presentations upon which no value was put at all. Sundry debtors represented various amounts for advertisements, business accounts, etc., which were outstanding at the date of the closing of the books, and which naturally were paid in the usual course. The bank balance showed that the Institution had on deposit the respectable sum of £1,143 19s. 8d., and there was also a current account of £241 14s. 4d. The result of it all was that the revenue account showed a credit balance of £1,367 6s. 6d., which, as he had previously said, was the aggregation of unspent income up to date. The Profit and Loss Account was shown in a slightly different form in the present accounts. It would be noticed that an amount for income tax appeared for the first time, the explanation of which was quite simple. Owing to a clause in the recent Finance Act it was discovered that the Institution, not being an Institution formed for charitable purposes entirely, had to pay income tax on interest and dividends where the tax was not deducted before the payment of interest and dividends, and the Institution had to pay the tax for two or three years back. That could not be avoided, and the item therefore appeared in the accounts as a payment made. It would also be seen that an item appeared for the first time under "Journals." In past years the Journals were always included in the item of "Printing and Stationery," but the Council considered that it would be more satisfactory to separate the cost of producing the Journals so that the members could see without any difficulty the net expense of the publications. Formerly that was mixed up with another item and it could not be seen. Therefore, the present item of printing and stationery in the Profit and Loss Account represented only the cost of ordinary office stationery and ordinary printing, but not the Journal, and the item of "Journals" represented the net cost of producing the Journals, after taking credit for the sales and the advertisements. Incidentally the sales and the advertisements showed a considerable increase upon the amounts realised for the same items in 1923. The other figures were, as far as he could see, quite familiar and usual and did not appear to need any particular comment. It would be noticed from the Report that the membership was continually increasing, and he thought the members would agree with him that the position of the Institution was quite satisfactory. He begged to second the proposition that had been moved from the Chair that the Balance Sheet and the Accounts be approved and adopted.

**The President** said he was sure the members were very much obliged to Mr. Adams for the clear way in which he had explained

the accounts. It was now open to any member to ask any question on the accounts or to make any remarks.

No remarks being forthcoming, the motion for the adoption of the accounts was put and carried unanimously.

On the motion of MR. M. A. OCKENDEN, seconded by MR. W. E. GOODAY, the retiring Auditors, Messrs. Price, Waterhouse & Co., were unanimously re-elected.

**The Secretary** announced that five members were nominated for election to the Council, two of whom were members elected during the year by the Council in accordance with the by-laws, and three other members. The result of the ballot was that the two retiring members, Mr. T. Dewhurst and Mr. W. Sutton, had been re-elected, and Mr. E. Lawson Lomax and Prof. A. W. Nash had been elected Members of the Council.

**The President,** on behalf of the Institution, said he desired most heartily to welcome the two new Members of Council, Mr. Lawson Lomax and Prof. Nash. It also afforded him much pleasure to announce that the Council had elected two new Honorary Members—namely, Dr. Mrazec and Dr. Edelenau.

Before reading his valedictory address he would like to say a few words on the work of the Institution in addition to the information contained in the Report. In the first place he desired sincerely to thank the Council and Members for the very generous support they had given him during his term of office as President. It was entirely due to their efforts that the Institution had gained in strength and position, as he was sure all would agree it had done. The increase in membership would have been noted, which he thought was satisfactory considering the somewhat limited field from which the Institution was able to draw for its membership. The thanks of the Institution were due to Mr. Adams, the Chairman of the Finance Committee, for his very wise and able direction of the finances. The Institution was also to be congratulated on the increasing importance of the Journal, the demand for which had greatly increased, 1,200 copies of each number now being printed, so that it would be appreciated that it was very widely distributed. As one of the former Presidents had remarked, the success of the Institution was due to the fact that it fulfilled a real need in the industry, and he looked forward with confidence to a still more rapid advance in the future; and he trusted that not only the industry, but the Institution would establish a record in that direction. The Council were greatly encouraged by the good work done by the students, and personally he felt sure that their influence in the industry would be increasingly evident during the next few years.

**The President** then delivered the following valedictory address :—

## The Uses of Petroleum, with Special Reference to the Production of Power.

By H. Barringer, M.Inst.C.E., M.I.Mech.E., M.I.N.A., M.Inst.Mar.Eng.

The question of selecting a subject for my second and valedictory address has presented some difficulty, but up to the present it has been the rule that the President shall present an address on the completion of each year of office. In complying with same it has occurred to me that a few remarks on the general uses of petroleum, especially in reference to the production of power, might be of interest. The subject covers such a wide field that only a brief reference is possible.

Petroleum in its crude state has been known to the world since the earliest times, numerous references to bitumen being found in the classics, and it is somewhat curious that its use for so many centuries should have been confined, as far as we know, to its employment in its crude state only, probably as a preservative or waterproofing agent and possibly for light in the form of torches, etc.

This is the more remarkable when it is remembered that it was only about the end of 1861 that the first cargo of petroleum, consisting of 224 tons in barrels, was delivered in London by the brig "Elizabeth Watts." In the comparatively short space of 64 years, the industry has developed probably more rapidly than in any previous instance, until it holds the important position which it does to-day.

The first general use of refined petroleum was for lighting purposes and this is still an important item of consumption

Its excellent properties as a lighting agent provided impetus to the design and improvement of lamps, which have attained a high order of efficiency, In the early days of oil lamps, numerous accidents occurred through their being upset, and in some cases explosions of petroleum vapour, which eventually led to a standard flash point being fixed and lamps being designed which were extinguished on being overturned. Some very powerful plants for use in lighthouses have been installed and have given excellent results, and in case of fog are generally supposed to be preferable as giving further penetration than electric illumination. Before leaving the subject of lighting, mention should also be made of paraffin wax. Before the advent of petroleum, tallow candles were largely used for domestic purposes, and where cost did

not prevent, bees' wax candles were used. The old tallow candle required constant snuffing, and it was not until the device of plaiting the wick so that on burning it curled over and came outside the body of flame, thus being consumed, that this difficulty was overcome. At the present time paraffin wax provides a clean and hard candle giving a good light and at a moderate price.

From lighting the adaption to use for heating, including cooking, was but a short step, and very efficient stoves are now obtainable and are largely used.

Following the import of burning oil, kerosene or paraffin, as it is generally called, the lighter products commenced to be brought into use. I believe the first petroleum spirit was known as benzoline and was extensively used in lamps, the receivers being filled with sponge, which absorbed the spirit and avoided the danger of free liquid. The wick, being inserted in the sponge, provided a good light, especially for portable lamps, which did not necessarily require a chimney. Spirit vapour has also been used as an illuminant, vapour being distributed by pipes in the same manner as ordinary coal or acetylene gas.

The value as a cleaning agent was also soon appreciated, and a considerable amount is at the present time consumed for this purpose. The dangers from fire and explosion in the use of petroleum spirit are now well understood, and precautions taken have greatly reduced the number of accidents.

The use of petroleum products in the manufacture of modern explosives is well known.

In medicine, preparations from petroleum are freely used both as external and internal lubricants, the latter in abdominal troubles. I am told one of the advantages being that these drugs are not digested or absorbed into the system when taken internally.

Probably one of the most important benefits petroleum has rendered to hygiene is that of the suppression of malaria by the destruction of the fever-carrying mosquito; by the spreading of oil on surface of swamps and stagnant waters where these insects breed they are destroyed as they emerge at the surface.

*Road Making and Surface Treatment.*—The use of bitumen and oil in various compounds both for the consolidation and surface treatment of roads has completely revolutionised the matter of road travel. In the days of horse transport it will be remembered that in certain districts during the dry weather the roads were inches deep in fine dust, which was stirred up in clouds on the passage of any vehicle; the faster moving and more numerous motor cars rendered the dealing with this question imperative, and thanks to petroleum and its products one can travel the length and breadth of England with very little inconvenience from dust. A considerable amount of research and experiment is still required

before the best type of road both as regards suitability for heavy traffic and satisfactory surface especially in wet weather is evolved.

The proportions of oil to stone used in road making vary according to the type of material available, conditions of traffic and the climate. In Egypt, where oil is extensively used in road-making, the proportions found suitable are 55 kilos bitumen per cub. metre of stone, (about 1½ tons), with a sealing coat of 10 kilos per sq. metre, finally sprinkled with clean basalt chippings.

*Lubricating Oil.*—Although for ordinary lubrication of machinery a mixture of mineral and vegetable oil is found to be the most satisfactory, for internal lubrication of cylinders, where oil is subjected to considerable heat, a mineral oil is essential. The correct disposition of the oil itself between the surfaces to be lubricated has done much to obtain the best results from the oils available. The Michel bearing may be instanced in which very high pressures have been successfully dealt with.

In the selection of a lubricating oil for air compressors and scavenging-pumps for Diesel machinery great care should be taken, otherwise an explosive vapour may be generated and inflamable deposits formed. There have been several accidents from this cause.

In the case of internal lubrication of steam cylinders and of piston rods, it is imperative to use a mineral oil, otherwise large deposits are formed, and acids produced which give rise to corrosion in boilers and pipes.

Petroleum as a fuel has been found very suitable in the manufacture of glass and in the heating of forges and furnaces for dealing with constructional steel work, the protection of structures against weather and corrosion; as an insulator for electrical converters; in the enrichment of coal gas, and in warfare the production of smoke screens, and generally its use would be more extended were its cost reduced.

*Power Production.*—Petroleum and its products, as stated, enter so largely into such various manufactures that it would be difficult to mention them all. I therefore propose in conclusion to deal with one of its most important uses, *namely*, the production of power. Dealing first with oil used as a fuel in place of coal as a steam producer, it has been principally employed for this purpose at sea, although it is also largely used ashore. Its use at sea offers several special advantages. In the first place it is more efficient than coal, and consequently a less weight of bunkers is required for a given distance and more cargo can be carried; fewer firemen and no trimmers are required, owing to there being no hard manual labour necessary in bringing fuel to stokehold feeding furnaces, and removing ashes, etc. This, in large powered vessels, amounts to a very considerable saving. It is clean in

its use, the operation of bunkering can be carried out more expeditiously and without the attendant dirt and dust inseparable from coal, and a steadier steam pressure can be maintained at sea.

There are now three principal systems in use for dealing with oil as a steam-raising fuel :—

1. The spraying of the oil by the agency of a steam jet into mouth of furnace, oil being fed to burners by gravitation.
2. The same process but, instead of steam being used as the atomising agent, compressed air is employed.
3. The pressure system in which oil is pumped to burners, the pressure being used as the sole atomiser.

The principal objection to the use of the first system at sea lies in the use of steam and consequent loss of fresh water from boilers. It is also less economical than the pressure system.

In the case of atomising by air pressure, this is also less economical, and the keeping of air compressors in good order and the maintaining of a steady air pressure also present difficulties.

Undoubtedly the pressure system is the best for use at sea, and is generally adopted. In all cases the oil is heated and strained before entering burners, the temperature and pressure varying with different classes of oil ; in the case of heavy Mex fuel temperature often rising from 250 to 300° F., and pressures from 50 to 90 lbs. per square inch.

In the case of the steam jet system the amount of steam used in the installation is stated to be about 4 to 5 per cent. of that generated in the boiler, in the air pressure system 3 to 4 per cent., and in the pressure system 1 to 2 per cent. In all cases this covers use for all purposes, pumping, air compressing and heating. Percentages, of course, vary with different classes of oil. In the case of the steam jet the steam is lost, but in the other two systems it is condensed and returned to boilers. The principal point at sea is not so much the amount of steam used as the amount of fresh water lost, and except in the case of the steam jet, this should be very little.

A large proportion of the liquid fuel now supplied requires heating in the bunkers before it can be pumped, in addition to the heating required to raise it to the best temperature for atomising and burning. Heating also assists in separation of any water held in suspension in the oil. A certain amount of water is often found in bunker oil, and it is important that this should be drained off before using, as in addition to the trouble with burners being extinguished, the presence of water in oil, even if not sufficient to put out flame, has a serious effect on the economy of combustion. Forced draught using heated air is generally fitted in liquid fuel installations, one great advantage of this system being the easy and effective distribution of air to furnaces, which is such an important matter in the efficient burning of oil.

At the present time the most effective arrangement for the burning of oil for the generation of power by steam is the pressure system, using forced draught, supplying heated air, the steam being superheated and operating high-speed turbines, carrying a high vacuum in condensers. In the case of sea-going vessels, double reduction gear is introduced in order to reduce revolutions to a required propeller speed. The consumption with quadruple reciprocating engines over long periods has been brought down to 1 to 1·15 per I.H.P. for all purposes.

As illustrating the advance that the use of oil at sea as a steam generator has made during the last ten years, Lloyds' figures show that in 1914 the world's tonnage of vessels fitted for burning liquid fuel amounted to 1,310,000 tons, and at the end of 1924 this figure had increased to 17,154,000 tons.

Probably the most interesting feature in the use of heavy petroleum at the present time is the development of what is known generally as the Diesel Engine, especially its use at sea.

Dr. Diesel produced his first engine in 1897, after eight years of experimental work, and as soon as the first practical engine was finished tests were made and attended by many engineers. This engine consisted of a single cylinder (4 cycle), 10¼ in. diameter, with a stroke of 16½ in. and developed, at 200 r.p.m., about 20 B.H.P., with a consumption of 0·486 lb. of oil per B.H.P. Mr. Carsund, of Nobels, was much impressed by the results, and persuaded the company to take out licences and commence the construction of engines in Russia. It was, however, found that it was necessary to practically re-design the German engine as, having been constructed for the burning of paraffin, it was not suitable for the crude Russian oil which it was intended to use.

The Nobel engines were eventually a success, and among the first made were those for the pumping station on the Baku-Batoum pipe-line and were of about 100 B.H.P. each, having 2 cylinders.

The first Marine Diesel was also construted by Nobels and fitted on a tank vessel, the "Szarmet", in 1903, and did excellent work, and in 1907 they constructed the first 4-cycle reversible marine engine ever built. This developed 120 B.H.P. at 400 r.p.m., and had three cylinders, 10¾ diameter by 11¾ stroke, and was installed in a Russian submarine.

It is somewhat curious that Russia, through the Nobels, should have been so much to the fore and have contributed so largely to the development of the internal-combustion engine. Great Britain however, was not far behind, as in 1897 Mirrlees Watson took out licences and built Diesel machinery. They were the pioneers in this country.

It may be well here to state that, generally, the internal-combustion heavy oil engine, as distinct from the petrol or gasoline, may be

roughly divided into three classes. Those where the ignition is effected by a hot-bulb; those relying on the heat of compression of air, in which the fuel is blown into the cylinders by a compressed air charge; and those known as solid injection which dispense with the air blast. These, again, may be divided into the 4-stroke cycle, and those of the 2-stroke, in which latter the products of combustion are removed from the cylinder by a scavenging air blast, and the double-acting engine.

The various designs of Diesel engines are so numerous that it would require numerous papers to describe them, and I do not propose to enter into many details of mechanical design, but it may be of interest to mention the results of some tests made on one or two types, together with the result of the actual running at sea of vessels fitted with Diesel machinery.

In the 2-cycle engine the piston receives an impulse at every revolution, and in the 4-cycle every two revolutions, therefore, if piston speed, mean pressure, and size of cylinder remain the same, twice the power will be developed by the 2-cycle engine, thus allowing a saving of weight and space. A scavenging pump is required in the 2-cycle.

As regards temperatures, it may be taken that the mean temperature of the complete cycle in the 2-stroke engine is somewhere about 20 to 25 per cent. above that of the 4-cycle. The mean temperature of a 4-cycle engine at full load is about 900° F., that of the 2-cycle, which is developing twice the power, being in the region of 1100° F. when working at the same mean pressures. It will readily be seen that much depends on the design and material, especially of covers and pistons, to avoid trouble through cracking of castings.

It will be noted that compression pressure generally amounts to 500 to 600 lbs. per square inch, and in the air injection type the air blast pressure from 700 to 1000 lbs. The mean effective pressure from 75 to 120 lbs., according to load, and consumption per B.H.P. about 0·39 lbs. to 0·44 lbs. In the early days some trouble was experienced with compressors, but this has now been overcome by the use of three-stage compression. It is, of course, necessary to cool the air, and great care should be exercised in the inspection of coils, as in some cases these have rapidly corroded and accidents have happened. It is good practice to carefully weigh these coils when new, and from time to time repeat the process, and should the weight fall 25 per cent below the original, coils should be at once renewed.

In the solid ignition system no air blast is used, but oil is introduced into cylinder at a very high pressure. 3000 to 8000 lbs. or more per square inch, and although compressed air is not required whilst engine is running, it is generally required for starting and manœuvring.

In the matter of mean indicated pressures, these, of course, greatly exceed those possible with steam. In the case of a steam engine, a mean pressure being taken and referred to the low-pressure piston, together with piston speed, is accepted as the power which the engine will safely develop, and boilers are designed to supply the required pressure and amount of steam, but in the case of a Diesel engine the power developed within limits is governed by the amount of fuel supplied, and overloading must be avoided; for ordinary running a mean indicated pressure of about 95 lbs. per square inch has been found suitable, although engines have been and are often run at higher pressures, up to 125 lb. or more, without developing trouble. The proportion of initial to mean pressure in oil engines sometimes amounts to 7 to 1.

It might be expected that the mechanical efficiency or ratio of B.H.P. and I.H.P. would be lower in the 2-cycle engines than in the 4-cycle on account of the power required to drive the scavenging pump, which absorbs about 6 per cent. of B.H.P. generated, but it must be borne in mind that in the case of the 4-cycle engine the frictional losses are heavier, and that there are certain "pumping losses" during inlet and exhaust due to friction of air and exhaust. From experiments made there appears to be little difference between the two types.

Although the 2-cycle engine appears to be gradually coming into more favour, the number fitted as regards marine machinery is considerably less at the present time than the 4-cycle, as shown on chart (p. 111) compiled from Lloyd's, by which it will be seen that nearly 1,021,000 tons of shipping of over 2000 tons is fitted with 4-cycle, whereas the tonnage fitted with 2-cycle engines amounts only to about 250,000 on the same basis. It will also be noted that the Burmester and Wain type heads the list.

In 1914 the tonnage afloat fitted with internal-combustion engines was only about 230,000 tons, and it now amounts to nearly 2,000,000, and last year over 500,000 tons of shipping was completed or under construction. In Germany Denmark and Sweden 78 per cent. of the shipping tonnage is fitted with internal-combustion machinery.

Above 350 r.p.m. the 4-cycle is a more compact engine and may be taken as most satisfactory, but for heavy slow-running machinery the 2-cycle appears to be more suitable. Unless we can improve our material, or in some way modify cylinder construction, it appears that we have about reached the maximum power which can be developed in one cylinder 2-cycle single acting. With the double-acting engine machinery now under construction 1000 h.-p. per cylinder will be developed.

*Burmester and Wain* in 1904 were fully equipped, and were turning out stationary engines, and in 1911 they had manufactured some

## FULL POWERED DIESELMOTOR STEEL SHIPS OVER 2,000 GROSS TONS IN ACTUAL SERVICE AS SHOWN BY LLOYD'S DAILY INDEX.

SEPTEMBER 2ND, 1924.

| Engine Types | Gross Ton | Number of Ships |
|---|---|---|
| BURMEISTER AND WAIN .. .. | 764,787 | 136 |
| WERKSPOOR .. .. .. | 67,944 | 17 |
| DOXFORD .. .. .. .. | 62,920 | 11 |
| VICKERS .. .. .. .. | 56,985 | 10 |
| SULZER .. .. .. .. | 53,637 | 10 |
| NORTH-BRITISH DIESEL .. .. | 40,858 | 7 |
| M. A. N. .. .. .. | 34,062 | 7 |
| FIAT (ANSALDO SAN GIORGIO) .. | 30,258 | 5 |
| ATLAS .. .. .. .. | 29,005 | 7 |
| CARMICHAEL-FULLAGAR .. .. | 25,748 | 6 |
| KRUPP .. .. .. .. | 24,555 | 3 |
| TOSI .. .. .. .. | 15,148 | 4 |
| MCINTOSH AND SEYMOUR .. .. | 10,225 | 4 |
| BETHLEHEM .. .. .. .. | 6,891 | 1 |
| KNUPP .. .. .. .. | 6,000 | 1 |
| STILL .. .. .. .. | 5,944 | 1 |
| CARELS .. .. .. .. | 5,703 | 1 |
| NOBEL .. .. .. .. | 3,756 | 1 |
| HOLEBY .. .. .. .. | 3,013 | 1 |

24,000 b.h.p., and it was at this date that they had made considerable progress with the marine type. The first large vessel engined by them was the "Selandia," completed in 1912, followed by the "Jutlandia," these being the first large ocean-going vessels so equipped. The machinery consisted of a twin set of 2000 h.-p., there being eight cylinders in each set working on the 4-cycle system. These vessels were a great success and are still doing good work. Messrs. Harland and Wolff, including sub-licences, have fitted some 270,000 tons of shipping with this machinery.

The most recent development is in the direction of making the ordinary 4-stroke engine double acting, thus obtaining double the power per cylinder. Those now under construction on this principle include three mail vessels fitted with twin or multiple screws, the machinery developing some 20,000 h.-p. One of the difficulties with the double-acting engine is the packing of the piston rod; in the Harland and Wolff engine the rods are surrounded by a cast iron sleeve, which protects the rod from the hot gases. With the exception of arrangements for protection of rods and the position of inlet valves, the general characters of the single-acting engine have been retained. In the Werkspoor double-acting engine this difficulty is said to have been overcome by arranging a separate combustion chamber below the piston.

In addition to the ordinary type of Diesel engine, the opposed piston type is favoured by some builders, and has given good results.

In Messrs. Doxford's design the lower piston is connected direct to a crank and the upper one to a crosshead above the cylinder, from which connecting rods (one each side of cylinder) rotate two cranks, the fuel being, of course, introduced between the upper and lower pistons.

In the Camellaird-Fullagar engine, also of the opposed piston type, the lower pistons are connected direct to a crank, but the upper ones are connected by diagonal rods to the lower crosshead of the adjacent cylinder, the diagonal rods crossing, the thrust being taken by guides. This engine also is doing excellent work and runs very steadily with little vibration.

The following is an extract from tests made by Prof. Rasbor at Nynashaum on a Nobel engine :—

Engine.—2-stroke cycle, 4 cylinders.
Diameter of cylinders, 26·3 in., stroke 35·8 in.
Diameter of scavenging pumps, two double-acting, 35·8 in. × 26·5.
Air compressor, 3 stage.
Dia. L.P. 21 in.
H.P. 4·29 and 22·2 stroke.
Int. 9·75.
Cooling water pumps, two, 4·8 in. × 14 in.
Fuel, 0·86 sg. at 20° C.
Calorific value, 10,000 cal. kg.

Flash point, 74° C.
Press. air bottles at starting, 260 lb. per sq. in., falling to 213 lb. per sq. in.=230 cu. ft. at atm. press. to rotate engine before firing.
B.H.P., 1752 at 106 rev. per min.
Mean effective press. on B.H.P. basis, 85 lb. per sq. in.
Fuel consumption, 0·4 lb.

*Scavenging* :
Air press. scavenger, 42 in. water column.
Temp. of exhaust, 330° C., a large amount of scavenging air being used.
Analysis of exhaust gases :—

| | | |
|---|---|---|
| $CO_2$ | 4·75 | per cent. |
| $O_2$ | 14·40 | „ |
| CO | 0·10 | „ |
| N | 80·75 | „ |
| | 100 | |

Blast press., 588 lb. per sq. in. to 882 lb. per sq. in.
Compression press., 441 lb. per sq. in., rising to 544 lb. per sq. in. during injection and combustion period.

In the Armstrong Sulzer 2-cycle engine one of the principal features is the method employed in scavenging; as the piston moves down it uncovers the upper scavenging port, but the rotary valve being closed no action takes place; as the piston moves further down, the exhaust port on opposite side of cylinder opens and exhaust commences, the pressure in cylinder being at once relieved, so that when the piston descends still further the lower scavenging port is opened (the valve on upper port also opening); air enters the cylinder through both ports and sweeps out the remaining exhaust products. The admission of air still continues on the upper stroke through upper scavenging port after exhaust and lower port is closed and provides the air for compression, this being slightly above atmospheric pressure.

EXTRACT FROM SHOP TESTS, ARMSTRONG SULZER ENGINE, 2-CYCLE, 4 CYLINDERS.

| | No. 1 Test. | No. 2 Test. |
|---|---|---|
| Mean B.H.P. | 1001 | 1350 |
| Mean int. pressure | 79·4 lb. sq. in. | 95·4 lb. sq. in. |
| Mean mech. eff. | 68 per cent. | 70·2 per cent. |
| Consumption per B.H.P. | 0·384 | 0·39 |
| Jacket cooling water | 23·6 tons p. hr. | 35 tons p. hr. |
| Mean air compression stages, H.P. | 889 lb. sq. in. | 990 lb. sq. in. |
| „ „ „ I.P. | 139 „ | 157 „ |
| „ „ „ L.P. | 23·6 „ | 28·5 „ |
| Scavenger air press. | 1·17 „ | 1·16 „ |
| Lubricating oil general | 2·84 „ | 3·55 „ |
| Crosshead lubrication | 246 „ | 228 „ |
| Jacket cooling water inlet | 65°—72° F. | 65°—72° F. |
| „ „ discharge | 112° F. | 108° F. |
| Piston cooling water inlet | 65°—72° F. | 65°—72° F. |
| „ „ discharge | 86° F. | 97° F. |
| „ „ pressure | 64 lb. sq. in. | 67·5 lb. sq. in. |
| Air cooler H.P. inlet | 444° F. | 369° F. |
| „ „ outlet | 100° F. | 110° F. |
| F. A. I.P. inlet | 213° F. | 233° F. |
| „ L.P. inlet | 254° F. | 286° F. |

| | 1000 B.H.P. | 1350 B.H.P. |
|---|---|---|
| *Blast bottles* .. .. .. .. | 889 lb. sq. in. ... | 991 lb. sq. in. |
| Exhaust gases .. .. .. .. | 317° F. .. | 413° F. |
| „ pipe cooling water .. .. | 109° F. .. | 109° F. |

ARMSTRONG SULZER ENGINE.

Results of running at sea. *Conde de Churruca.* Twin screw. 3000 I.H.P.
March 4, 1922—November 7, 1923.

Average consumption, 8·5 tons per day. Av. revs., 91·2
„ speed 10·3 knots.

| | | |
|---|---|---|
| Lubricating oil per day, cylinders .. .. | 12·5 galls. | |
| „ „ other purposes .. .. | 10·0 „ | |
| Total all purposes .. .. .. | 22·5 galls. per day. | |

Total distance run, 102,988 miles.
In dock for hull repairs, September 19, 1922, to November 24, 1923.

The very high pressure of lubricating oil for crossheads will be noted.

RESULTS OF RUNNING AT SEA.

Doxford opposed Piston Type Solid Injection. S.S. *Westmoor*, about 1340 I.H.P.

Fuel, furnace quality.
Sg., 0·895 at 58° F.
B.T.U. about 19,000.

| | |
|---|---|
| Average consumption .. .. | 5 tons 10·6 cwt. per day. |
| Average speed .. .. .. | 10·2 knots. |
| Revolutions .. .. .. .. | 78·5 |
| Fuel oil pressure .. .. .. | 3600 lb. sq. in. solid injection. |
| Scavenger air pressure .. .. | 1·2 „ „ |

It will be noted that ordinary fuel oil is used, and Doxford's regularly test their engines with British Mex fuel oil of a specific gravity of 0·97, with which fuel they obtain a consumption of 0·39 lb. per B.H.P., with machinery developing some 3000 B.H.P. They attribute the successful use of this heavy grade oil mainly to the solid injection in conjunction with an efficient combustion space of spherical form and to the high temperature of the surface in which fuel comes in contact.

The spherical combustion space is formed by the two opposed pistons; the head of each piston is hollowed out so that when they are close together at commencement of stroke the two hemispheres enclose a spherical space with the small clearance between pistons dividing it; through this clearance space the oil charge is injected through two or more apertures arranged circumferentially, and spreads out in a fanlike form, by which a high state of turbulence is induced. The piston heads are kept at a very high temperature; the cup-like form of the heads also protects the cylinder walls against flame at the time of ignition. In the case of a single piston being used, the cylinder cover is hollowed to form the upper half of the spherical space. In the opposed piston type the exhaust ports are placed at top of cylinder and the scavenger ports at bottom, both of which are uncovered when pistons are furthest apart. The air enters with an upward and swirling motion, providing a very

complete scavenging action. It is stated that this engine will run at 15 r.p.m.

The question of fuel is governed principally by the trade in which vessel is engaged. The two classes of oil available may be roughly described as boiler or furnace oil and Diesel oil. The difference between these oils is fairly defined, and it may be briefly stated that the former is generally of a higher specific gravity and very much higher viscosity, and it may contain more impurities or a greater proportion of sulphur, and gives a greater residue on evaporation at a fixed temperature, but the price is generally about 20 per cent. lower than that of Diesel oil, although in some ports in the East there is little difference in cost.

It is doubtful in some cases if there is much saving in using furnace oil owing to extra straining and heating being necessary.

For specifications of fuel oil for heavy oil engines the publication issued by the British Engineering Standards Association may be referred to. It may be mentioned that the A specification fulfils Admiralty requirements with the exception that the flashpoint required must not be below 175° F. instead of 150° F.

The following are actual figures taken by chief engineer from bunkers supplied in accordance with Board of Trade requirements :—

| | Diesel Oil. | | |
|---|---|---|---|
| Brand. | Specific gravity. | Flash point, deg. Fahr. | Viscosity, Eng. |
| Persian "Mehor" M.V. .. | 0·895 .. | 180 .. | 2·22 |
| " .. .. .. .. | 0·895 .. | 180 .. | 2·22 |
| Borneo .. .. .. .. | 0·9502 .. | 176 .. | 1·7 |
| " .. .. .. .. | 0·941 .. | 164 .. | 1·44 |
| " .. .. .. .. | 0·9085 .. | 160 .. | 1·6 |
| " .. .. .. .. | 0·9085 .. | 160 .. | 1·6 |
| " .. .. .. .. | 0·885 .. | 162 .. | 1·6 |
| Persian Tantalus, M.V. .. | 0·891 .. | 167 .. | 2·61 |
| " .. .. | 0·891 .. | 167 .. | 2·61 |
| " .. .. | 0·891 .. | 167 .. | 2·61 |
| " .. .. | 0·877 .. | 176 .. | 1·5 |

It will be noted that the samples from each brand do not vary greatly.

Performance of vessels fitted with various types of machinery burning coal and oil.

Based on formula—

$$C = \frac{D^{\frac{2}{3}} \times S^3}{\text{Tons fuel per day all purposes.}}$$

D = Displacement of hull.
S = Speed, knots.

| | |
|---|---|
| Reciprocating engines, coal-fired boilers, lb. per s.h.p., 1·65 .. | C=16000 |
| Reciprocating engines, coal-fired, superheated steam (160·200), 1·5 | C=18500 |
| Turbine engines, coal-fired, superheated steam, 1·425 .. .. | C=19500 |
| Turbine engines, oil-fired boilers, superheated steam, 0·9 .. | C=30000 |
| Oil engine, 4-stroke, single-acting, 0·41 .. .. .. .. | C=64000 |

The above figures represent the averages of some eighty vessels.

The Richardsons Beardmore Tosi engine has also given good results.

One of the main features of this engine is the semi-rotary director valve which controls the suction and exhaust through the combined exhaust and suction valve, the one valve serving both purposes.

Very exhaustive tests were carried out by a Marine Oil Engine Final Committee on board the twin-screw motor-vessel *Sycamore*, 4-cycle, air-injection, fitted with above-mentioned engines. Anglo-Persian Diesel Oil was used, the average analysis being :—

| | | |
|---|---|---|
| Gross calorific value | | 19323 B.T.U. |
| Specific gravity | | 0·8777 |
| Flash point P.M. closed | | 189° F. |
| Viscosity Redwood No. 2 | at 32° F. | Oil would not flow. |
| | at 70° F. | — 83 |
| | at 120° F. | — 47 |
| | at 222° F. | — 37 |
| Oil became viscous at | 41° F. | |
| „ thick at | 37° F. | |
| „ solid at | 31° F. | |

A slight trace of water.

*Chemical analysis.*

| | |
|---|---|
| Carbon | 84·8 per cent. |
| Hydrogen | 12·21 |
| Sulphur | 0·08 |
| Nitrogen | 0·07 |
| Oxygen | 2·84 |
| | 100·00 |

INTERNAL-COMBUSTION ENGINE LUBRICATING OILS (PALE OR RED).

| Classification. | | Typical Specification. | | | | | |
|---|---|---|---|---|---|---|---|
| Viscosity Grade. | Nonimal gravity at 140° F. (Redwood). | Specific gravity at 60° F. | Closed flash point. ° F. Min. | Viscosity (Redwood) seconds. at 70° F. | at 140° F. | at 200° F. | Cold test to be below ° F. |
| Extra light | 80 | 0·890/0·930 | 315 | 550/700 | 75/90 | 40/45 | 25 |
| Light | 100 | 0·890/0·935 | 335 | 700/1200 | 90/130 | 45/55 | 25 |
| Medium | 165 | 0·890/0·935 | 340 | 1200/3000 | 130/185 | 50/70 | 35 |
| Heavy | 220 | 0·890/0·930 | 350 | — | 185/260 | 65/80 | 35 |
| Extra heavy | above 260 | 0·890/0·920 | 375 | — | above 260 | above 80 | 40 |

Hard asphalt nil.

—*British Engineering Standards Association.*

From above analysis, the following quantities are calculated in respect to consumption of 1 lb. of fuel :—

| | | |
|---|---|---|
| (*a*) | Weight of $CO_2$ formed | 3·11 |
| (*b*) | „ steam | 1·10 |
| (*c*) | „ oxygen required (*a*) | 2·26 |
| (*d*) | „ „ „ (*b*) | 0·95 |
| (*e*) | Theoretical total weight air required | 13·90 |

THE LUBRICATING OILS USED WERE:

| | Special Diesel Rimer Crank case. | D.T.E. Heavy Vacuum Air Compartment Cylinder. | D.T.E. Extra Heavy Vacuum Power Cylinder. |
|---|---|---|---|
| Specific gravity at 60° F. .. | 0·8777 | 0·9035 | 0·8864 |
| Flash point .. .. .. | 374° | 400° | 401° |
| Viscosity Redwood 2, 70° .. | — | 834 | — |
| 120° .. | 180 | 207 | — |
| 200° .. | 66 | 55 | 71 |
| Coke content .. .. | 0·05 | 0·01 | — |

In reference to temperatures an attempt was made to ascertain these in certain positions by fusible alloys. As far as could be judged the temperature of piston did not exceed 626° F. Exhaust valve head 960° F.

Another type of oil engine, combined with steam, known as the "Scott-Still" should also be mentioned. In this engine, oil is the fuel used above piston on the usual Diesel principle, and steam on the underside of piston, thus making the engine double acting. A boiler, which is fired by liquid fuel burners, is provided and steam is raised in this boiler by which the engine is started and operated instead of with compressed air until oil charge fires. The cylinders are cooled by water of same temperature as that in boiler, say about 340° F. corresponding to a pressure of about 120 lbs. per sq. in. The steam generated in the jackets is passed to boiler. The steam used on underside of piston acts as a cooling agent for the piston and also itself becomes superheated. The jacket water is still further heated by a regenerator through the exhaust gases. The temperature of these gases is reduced from about 700° F. to 186° at discharge. Steam is, therefore, generated by the waste heat through cylinder walls and that contained in the exhaust gases. When engine is at work on full load, the oil burner is shut off and steam maintained entirely by the waste heat. About 10 per cent. of the power provided by oil is obtained from the steam. The cylinder liners are made thin, being specially strengthened in their design and receiving support from jackets. The pressure of water, about 120 lbs. per sq. in., also lends additional support.

Extensive trials have been made with promising results, and an ocean-going vessel is, I believe, either fitted or to be fitted with this engine of about 2,500 h.p. The design certainly has attractions.

Many vessels fitted with internal-combustion engines are supplied with a steam boiler, to deal with auxiliaries such as winches, windlass, steering gear and whistle; in the Scott-Still a boiler is provided in any case which can deal with the above. When in port, and main engines not running, it is oil-fired in the ordinary way.

The advantages claimed for the Scott-Still engine may be set out as under :—

1. Heat to cooling medium raises steam.
2. Steam below piston cools engine and itself is superheated.
3. Hot jacket enables lower compression to be used.
4. Uniform temperature of whole cylinder liner obtained.
5. Water pressure in jacket reinforces liner.
6. A thin liner can be used giving lower temperature stresses.

The amount of heat passing through cylinder walls, etc., in a given time increases roughly in the ratio of the fourth power of the absolute temperature of the gas so that with a combustion temperature of 3000° F. about four times as much heat will pass as with a temperature of 2000°.

Another type of engine which embodies some novelties may also be mentioned—*viz.*, that built at the North British Diesel Engine Works. In this design there is an upper and lower cylinder firmly connected together by ties but with a space between sufficient to accommodate a gudgeon passing through a double-ended piston which carries the top ends of connecting rods one on each side of cylinders. By an arrangement of links the cylinders are caused to reciprocate in addition to the piston, the travel of the former (13½ in.) being less than the latter (44 in.) but the motion, being synchronised, reduces the rubbing speed of piston on cylinder liner. The ends of cylinders move in the cylinder covers and are fitted with packing rings The exhaust outlets and scavenger air inlets also slide in sockets. A double acting 2-cycle engine is thus obtained without having any piston rod exposed to hot gases.

The advantages claimed are :—

1. End to end scavenging.
2. Parts subjected to heat greatly simplified. No piston rod.
3. Cylinder covers and liners being free to expand larger diameter cylinders can be safely used.
4. Accessibility of internal parts improved.
5. Rubbing speed of piston reduced by nearly 30 per cent.
6. Lower bearing pressures.

The internal combustion engine is a very convenient and economical prime mover for oil-field work especially in regard to electrically operated fields where a large central power-station can be erected in a convenient position.

Although a very large number of stationary Diesel engines have been built for land work I have referred principally to those fitted on ocean-going vessels for the reason that there are certain difficulties attached to marine work which have to be overcome and also that as many of the vessels so fitted, being tankers, are engaged in the transport of petroleum.

Many tables have been published professing to show the advantages of the marine steam or oil engine as a propulsive agent. I have examined several of these and find that they differ greatly, generally on account of the variation in prices at which coal and oil are taken. Apparently the voyage which vessel makes is often a decisive point as to which of the two is the more economical. For instance, it has been calculated that a vessel of 8600 tons d.w., steam-driven, and a vessel of same dimensions of 8490 d.w., oil-driven, trading between this country and the United States, the former will in a year's working carry 77,000 tons of cargo and the latter 82,000 tons, this larger amount owing to a less weight of bunkers required and supposing both vessels to have full cargoes on every voyage. If coal is taken at 17s. 3d. per ton and oil at 66s. and allowing a freight rate of 20s. per ton, the steam-driven vessel would return 33·3 per cent. on capital expenditure and the oil-driven vessel 27·2 per cent. (McGovern, Mar. Eng.).

The price 17s. 3d. per ton for coal is very low, but I understand it has in some cases been bought at this figure; the cost of oil appears high. By taking coal at 32s. per ton and oil at 63s. the return on capital would be practically the same in each case.

In an Eastern voyage much better results would be shown by the motor-ship. It must be borne in mind that the first cost of the oil-driven vessel will probably be about 30 per cent. in excess of the steam-driven. Depreciation, maintenance and insurance have been taken at 5 per cent. in both cases. As to maintenance, in the case of the oil engine no reliable figures are available, but it may be taken that they will not be less than with steam and possibly more.

To sum up, it therefore appears that on certain voyages it will be difficult, at the present time, for a motor vessel to compete with steam, but for other voyages the motor vessel will prove the best. In the event of the prices of coal and oil more nearly approaching one another the motor vessel will still further improve its position.

In dealing with weights of various types of marine machinery it may be mentioned that the weight in torpedo-boat destroyers, geared turbine driven, is from 30 to 35 lb. per shaft-horse power, battleship, 70 to 80 lbs., Diesel cargo-boat about 650 lbs., and triple expansion steam about the same, probably about 10 per cent. lower.

As shown by Lloyd's figures, the use of the internal-combustion engine at sea is making rapid progress and no doubt will continue to do so for moderate powers, but for high powers steam operating turbines only can be used.

A great many types of internal-combustion engines are now in use, and no doubt as experience is gained in actual practice many

of them will be eliminated, design generally simplified, and within limits a standard type of engine will be evolved.

Reduced to percentages, the types of machinery constructed for service afloat from 1918 to 1924 are as follow :—

| Period. | Steam reciprocating. Per cent. | Steam turbines. Per cent. | Motors. Per cent. |
|---|---|---|---|
| 1918-19 .. | 70·0 .. | 28·0 .. | 2·0 |
| 1919-20 .. | 67·4 .. | 30·7 .. | 1·9 |
| 1920-21 .. | 73·6 .. | 23·3 .. | 3·1 |
| 1921-22 .. | 56·4 .. | 34·6 .. | 9·0 |
| 1922-23 .. | 52·3 .. | 37·4 .. | 10·3 |
| 1923-24 .. | 69·8 .. | 11·4 .. | 18·8 |

Of course the essential difference between the Diesel and the 4-cycle petrol type of engine is that in the Diesel engine the fuel is not introduced into the cylinder until the compression of air has taken place and the required temperature obtained to ignite the oil ; whereas in the petrol engine the charge consisting of the proper mixture of petrol vapour and air is drawn into the cylinder, compressed on the return stroke, and at the proper moment fired by an electric spark.

Supercharging is sometimes resorted to. This is accomplished by introducing into the cylinder, at about 95 per cent. of the downward stroke, air under a light pressure. The cylinder being full of a mixture of air and fuel, the additional air does not mix freely with the fuel and air at the time, but appears to form a layer over crown of piston. On the following stroke contents of cylinder is compressed. On the exhaust stroke air is also admitted which assists in the removal of the waste products. The additional air introduced in the cycle may amount to 40 per cent. of total cylinder volume, 34 to 35 per cent, being supercharge air, and about 5 per cent. scavenging air. With extra air in cylinder more fuel can be burnt, with a consequent greater output. In the ordinary 4-cycle engine the charge of air and fuel is slightly below atmospheric pressure.

The carburettor is an important fitting to the petrol engine as upon the correct mixture of vapour and air the efficiency and economy of the engine depend. One of the difficulties to be contended with is the maintaining of the right mixture, which varies under different conditions, including that of starting.

With petroleum in its form as a spirit, we find it (often in conjunction with benzol) as practically the only fuel used in motor vehicles and aeroplanes. Almost invariably the engines in which spirit or paraffin is used work on the 4-cycle system. There are various reasons for this, amongst them being the obtaining of a higher mean pressure and the ability to run at higher revolutions than the 2-cycle engine, thus securing an advantage in weight. The Diesel cycle of operation lends itself more favourably to the 2-cycle principle for large land and marine engines.

Illustrating the continual increase in the consumption of spirit and the important part it plays in the production of power, as applied to locomotion, there are now, by the latest returns, 1,242,845 mechanically driven vehicles in the United Kingdom. 474,261 of these are privately owned cars, the increase in 1924 being 91,723.

In the petrol engine probably the most important question is the obtaining of high compression without detonation as the power and efficiency of the engine depend upon this. The design of combustion space, the method of ignition of charge and the properties and mixture of the fuel used affect this.

In the first place it may be well to explain the nature of detonation as generally accepted.

When a mixture of hydrocarbon vapour and air is subjected to compression, and temperature of compression approaches that of self-ignition and is then ignited, in the process of combustion it compresses the unburnt portion of the charge until spontaneous ignition takes place and an explosion wave is set up which causes the noise known as pinking or detonation.

In the design of combustion space it is important to arrange this to induce turbulence, and it has been found that in petrol engines having two or more sparking plugs, a higher compression can be used without pinking than when only one plug is fitted; this on account of the flame having a shorter distance to travel, but two or more plugs are of little use unless sparking is perfectly synchronised; when only one plug can be fitted and that not in centre of combustion chamber, this should be placed at the hottest side in order that unburnt gases may be forced against the coolest part, and thus get rid of their heat more rapidly. Should detonation become very pronounced and continued for some time, temperature of plug points will probably rise until pre-ignition takes place, or self-ignition due to compression, before spark passes. It is possible for detonation in its incipient stage to take place without audible noise, and to be only noticeable by the harsh running of the engine.

By experiment it has been found that an engine in which compression was set at 4 : 1 and fuel nominally detonating at 5 : 1, and run all out at constant speed, everything ran well and smoothly; as the compression ratio was raised, the power output was increased up to 4·7 : 1, engine still running smoothly; from 4·7 to 4·8 : 1, slight harshness was noticeable; from 4·8 to 4·9 : 1, harshness considerably increased accompanied by noise and increase in vibration, and at 5 : 1 audible signs of detonation were distinct, but only when ignition was fully advanced and mixture at strength to give maximum power; at 5 : 1 engine would continue to run, but with slight pinking, but at 5·1 : 1 detonation increased in severity, and after five to ten minutes running pre-ignition would set in and power decrease; but at this compression if mixture were

enriched to give a slower burning, and ignition retarded, compression could be raised to 5·25 : 1 without detonation. The same result could be obtained by weakening the mixture, but range advantage would be too small to be practicable. By further enrichment of mixture compressoin could be carried to 5·4 : 1, but with a sacrifice of economy. Plotted curves show that with compression ratio 4·5 : 1, mean indicated pressure was about 126·5 lb. per square inch, gradually rising to about 131 lb. at 5 : 1, remaining the same until 5·1 : 1, and afterwards falling to about 125·5, the indicated thermal efficiency being 30 per cent. at 4·5 ratio, rising to 31·7 per cent. 5 : 1 ratio, and falling to 28 per cent. at 5·4 : 1 ratio. Detonation is, of course, affected by speed of rotation, partly due to the reduction in velocity of gases entering chamber and therefore loss of turbulence. Hot zones of temperature are also liable to form, especially in neighbourhood of exhaust valve, and this, combined with general stagnation, all tend to induce detonation or self-ignition. Generally it may be stated that the lower the rate of burning of fuel the less the liability to detonate.

The theoretical efficiency of a correct mixture at 5 : 1 compression is 38 : 8 per cent., and that of a 10 : 1 compression 45 per cent. Temperature will vary at this ratio from 2561° C. to 2756° C., according to richness of mixture.

Spirit to be used in high-compression engines, such as aeroplanes, should not boil at a temperature exceeding 150° C., and a certain proportion of aromatic hydrocarbons is required in most cases. To obtain the latter a blending with Benzol and Toluol is necessary.

By adding small percentages of the following a suppression of detonation is secured :—

Iodine.
Aniline.
Di-ethyl compounds.
Tetra-ethyl compounds.

On the other hand, the addition of

Bromine,
Oxygen,
Ethyl Nitrate

induces detonation.

There are, however, certain difficulties in the use of lead tetra-ethyl. 3 c.c. to one American gallon of gasoline is the proportion required ; even the application of this small quantity has a harmful effect on the sparking plug points, causing them to disappear. To overcome this ethylene di-bromide has been used. It is also stated that it has a deleterious effect on the lubricating oil, and, moreover, is very poisonous.

Generally speaking the various "dopes" advertised to prevent "pinking" and increase power and mileage are on trial found not to be altogether satisfactory. The general practice being, if not running on petrol alone, to use a mixture of petrol and benzol.

The highest development of the petrol engine is probably found in the aeroplane, where very high powers are required, and it is necessary to keep down weight as much as possible. In some of the larger engines, of 1000 h.-p., the weight has been brought down to 3 lb. per h.-p. The Packard Motor Company of America have built an experimental engine for aeroplanes having 12 cylinders arranged in V form, indicating 800 h.-p. at 2600 r.p.m., and it is stated that the weight works out at 1·34 lb. per h.-p. A similar smaller engine 500 h.-p. at 2000 r.p.m. at 1·04 lb. per h.-p. In the design of aeroplane engines the question of making them immune as far as possible from the dangers of fire is of the first importance.

The direction in which advance may be sought appears to lie in the use of higher compressions and the efficient application of weak mixtures, and possibly the improvement of fuel.

In conclusion I should like to say a few words in reference to the bearing which the notes I have read have on the work of the Institution of Petroleum Technologists. I venture to say there is no commercial or manufacturing firm where the advice of an expert is not of the greatest service, and I should like to see a member of our Institution in a position of consultant to every organisation dealing with or using a product of petroleum.

The fact that we have members competent to deal with any branch of the Petroleum Industry should be more widely known, and although a great deal has been done in this direction, especially as regards production, I am of opinion that constant efforts should be made to bring this matter to the notice of the general users of petroleum, which I am confident would be of advantage to the industry.

Our Student Section should also be further encouraged. The Institution is doing all that can be done with its funds, but more could be accomplished if the means were available.

I should also like to see the Institution able to encourage research work, a great deal of which is required.

The writer desires to acknowledge his indebtedness to Messrs. Armstrong, Doxfords, Harland and Wolff, and Palmers for their kindness in furnishing various details.

At the conclusion of the reading of the valedictory address, *The President* said it was now his duty to request the President-Elect, Sir Thomas Holland, to take the Chair. He thought the Institution were to be congratulated on securing as President a gentleman of such distinction. As far back as 1916 Sir Thomas

was elected the President of the Institution, but as he had to go abroad he was unable to take up his duties. The members were very pleased to know that, at the present time, Sir Thomas was in a position to devote sufficient time to the work, and he now had much pleasure in asking Sir Thomas to take the Chair.

The Chair was then vacated by Mr. Barringer, and taken amid hearty applause by the President Elect, Sir Thomas H. Holland, K.C.S.I., K.C.I.E., D.Sc., LL.D., F.R.S., F.G.S.

**The President** (Sir Thomas Holland) said he desired to acknowledge very sincerely the great honour the Council had conferred upon him in electing him to be President of the Institution. Although he appreciated the honour very deeply, he felt very much more the responsibility which had been thrust upon him. After the address by Mr. Barringer, to which the members had just listened, the feeling of responsibility for maintaining the standard which had been set by his distinguished predecessors oppressed him. According to the bye-laws of the Institution, the Council had the power, whatever the members might say, of electing the President. It was the duty of the President when elected to show, therefore, that their confidence in the Council had not been misplaced. With the advice of those who had gone before him in the Chair and are still Members of the Council, he hoped at any rate he would not let the Council down. He remembered in 1911–13, when Sir Boverton Redwood, the revered founder of the Institution, was with him as a member of Lord Fisher's Royal Commission on Oil Fuel and Engines, they had before them so many witnesses representing the technical side of the British Empire oil industry that Sir Boverton made the suggestion that in some way the three groups of technologists concerned ought to be gathered together into one family, united by their common interest in the production and consumption of oil—namely, engineers, chemists and geologists. He took it that the Council in selecting him to be President for the year had indirectly conveyed a compliment to the smallest of the three constituents of the Institution, the geological section. Geology was really useful to the oil winner and the oilfield owner, whatever might be said by the other two groups of oil technologists, and whatever be the impression that the members might obtain from the high pretensions that some geologists occasionally made. He hoped that he might serve the Institution at any rate in one small way. The headquarters existed in London of two great Institutions of mining which had defined their spheres of influence. The Institution of Mining Engineers had now by its bye-laws, sanctioned by a Privy Council Charter, decided to limit its activities to the mining of coal and stratified deposits; while the Institution of Mining and Metallurgy had decided to limit its activities to the

metalliferous ore deposits of a different form. The position of oil was never clearly defined. When a movement was being made with the object of obtaining charters for those two Institutions, the Institution of Petroleum Technologists had not been formed. For some time papers on oil, especially the geology of oil, were read to the Institution of Mining and Metallurgy, and that activity persisted for a while after the foundation of the Institution of Petroleum Technologists. Since then the Institution of Petroleum Technologists had shown itself to be the natural home for papers dealing with the geology of oil, and he hoped that that condition of affairs would continue. At any rate, as a Past-President, and, therefore, Member of Council of the Institution of Mining Engineers, and as President-Elect of the Institution of Mining and Metallurgy, he would take care that the sphere of influence of the Institution was not trespassed on by the others.

He now desired to propose a very sincere vote of thanks to Mr. Barringer, the retiring President. For two years past the Institution had had the benefit of Mr. Barringer's tactful but sometimes very firm management of the business of the Council. During the last two or three months Mr. Barringer had been laid aside by illness. He was perfectly certain that Mr. Barringer was missed at the meetings of the Institution and still more greatly missed at the Council and Committee Meetings. In his absence it had been necessary to take decisions sometimes on very difficuly questions, but he hoped in none of them had the Council been more indiscreet than they had been in the selection of Mr. Barringer's successor. He was perfectly certain that every Member of Council would agree with him that the meetings had been conducted and the business guided by a common-sense tactfulness, sometimes with a strength and firmness, that everyone had greatly admired. With regard to the address that had been just delivered, as a simple-minded geologist he could only open his mouth with admiration. Every engineer, however, would agree that the address would be regarded as a reference work on the engineering aspects, especially of the consumption of oil. It was an address the purport of which could not be taken in at once because there was too much in it, but the number of the Journal in which it appeared would become of special value accordingly. He had the very greatest pleasure in proposing that the sincere thanks of the Institution be accorded to Mr. Barringer, first, for the conduct of the business of the Institution during the past two years; and secondly, for the address he had delivered that evening.

The resolution of thanks was carried by acclamation.

**Mr. Herbert Barringer,** in reply, thanked the President very sincerely for the kind words he had used in proposing the vote of

thanks, and the members for the hearty manner in which they had been received. He was afraid the President was a little bit sanguine about his address. It was only a sketchy sort of address, because the subject was so vast that it could not be dealt with in the time that had been placed at his disposal. It might lead, however, to other people thinking about the subject. It was hardly necessary for him to say that he was delighted to be present again at a meeting of the Institution. It had been his one great disappointment that he did not carry out his intention of going through his two years of office without missing a single meeting, but, unfortunately, that record had been broken in the last two or three months owing to his illness. He had no doubt that Sir Thomas Holland would beat him in that respect; at any rate he hoped he would. In conclusion, he again thanked the members for their vote of thanks, and especially the Members of the Council for the way in which they had carried on during his absence. He was quite sure they had done very much better than if he had been present at the meetings.

The meeting then terminated.

## THE INSTITUTION OF PETROLEUM TECHNOLOGISTS.

### Seventh Annual Dinner.

THE SEVENTH ANNUAL DINNER of the Institution of Petroleum Technologists was held at the Connaught Rooms, Great Queen Street, London, on Tuesday, 17th March, 1925. Sir Thomas H. Holland, K.C.S.I., K.C.I.E., D.Sc., F.R.S., occupied the Chair, and was supported by Mr. H. Barringer, Sir Frederick W. Black, K.C.B., and Professor J. S. S. Brame, Past-Presidents; Mr. Arthur W. Eastlake and Mr. Robert Redwood, Vice-Presidents; Mr. Ashley Carter, Mr. T. Dewhurst, Mr. James Kewley, Mr. T. C. Palmer, Dr. W. R. Ormandy, and Mr. William Sutton, Members of Council, and a number of members of the Institution.

The guests of the Institution included, among others, Sir Robert Burton Chadwick, M.P. (Parliamentary Secretary to the Board of Trade), M. Paul de Chambrier, H. Edwin Coley (Chairman, Chemical Industry Club), Engineer Vice-Admiral Sir Robert B. Dixon, K.C.B. (Engineer-in-Chief to the Navy), Dr. Bernard Dyer (Chairman, London Section, Society of Chemical Industry), Dr. J. W. Evans, C.B.E. (President, Geological Society), W. St. D. Jenkins, G.B., C.B.E. (Director of Contracts, Admiralty), C. McDermid (Secretary, Institution of Mining and Metallurgy), Humphrey M. Morgans (President, Institution of Mining and Metallurgy), J. W. L. Oliver, C.B., C.B.E. (Director of Naval Stores), George Patchin (Sir John Cass Technical Institute), Sir Joseph Petavel, K.B.E. (Director, National Physical Laboratory), Francis E. Powell (Anglo-American Oil Company), Air Vice-Marshal Sir W. Geoffrey Salmond, K.C.M.G., C.B., D.S.O. (Air Member for Supply and Research), W. C. Sneath, Admiral W. Stokes-Rees, C.B., and Douglas Vickers.

#### "THE KING."

THE PRESIDENT, in proposing the toast of "The King," expressed the sincere wishes of the Institution for His Majesty's speedy recovery.

The toast was accorded musical honours.

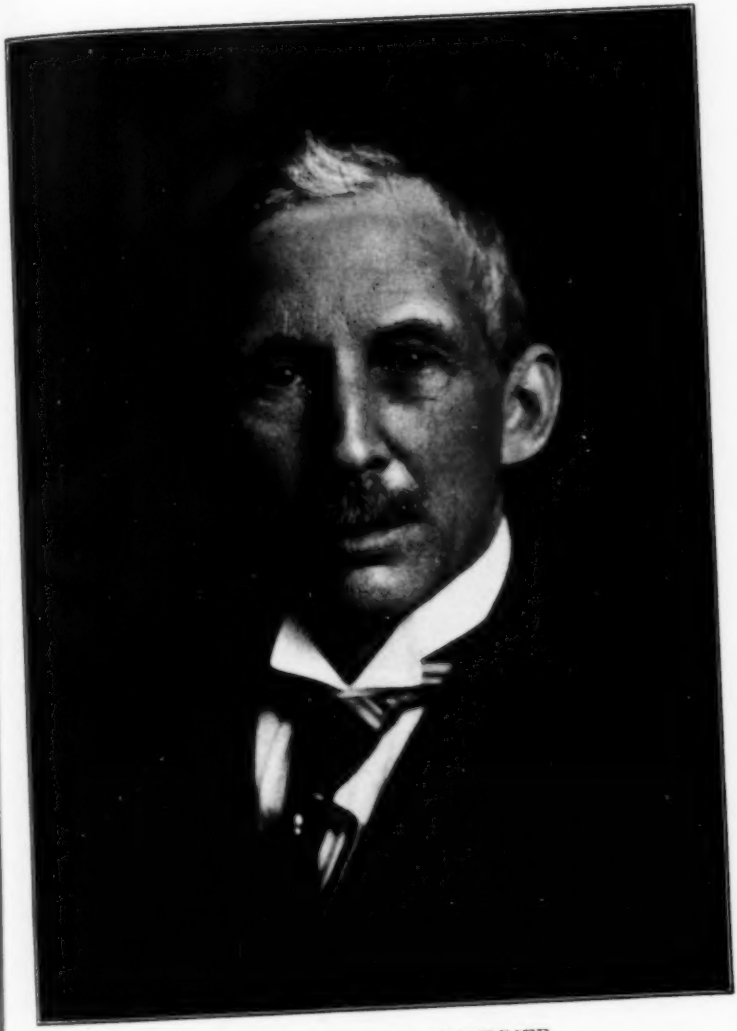
## PRESENTATION OF THE BOVERTON REDWOOD MEDAL TO M. PAUL DE CHAMBRIER.

**The President** : I have now a very pleasant ceremony to perform, namely, to present, for the first time in the history of the Institution, the Boverton Redwood Medal. The Medal was established through the generosity of Mr. Alexander Duckham to commemorate the late Sir Boverton Redwood, who was the founder of this Institution and its first President. Sir Boverton was, as you all know, for a generation or more an outstanding and possibly the most distinguished figure in the petroleum world, and one whose memory will always be held in affectionate respect by everyone connected with oil technology. (Hear, hear.)

The Council during 1924 gave very careful consideration to the conditions under which this new Medal should be awarded, and decided that it should be given every two years to the author of the paper which, in their opinion, was considered to be of the greatest and also of sufficient merit in advancing our knowledge of the technology of petroleum. It was decided by the Council that, in the first instance, papers should be considered from as far back as 1919, the first year following the war. There are, therefore, two biennial periods to be taken into consideration—1919–1921 and 1921–1923. The Council decided to make the first award of the Medal for the paper which was read before the Institution on February 15th, 1921, by M. Paul de Chambrier, who described the revised method of working, by means of shafts and galleries, the petroleum deposits at Pechelbronn in Alsace. For the second period it was found that we could not justifiably make an award.

It is interesting to find that our first choice for this distinction is in connection with a method of petroleum exploitation radically different from that by which over 99 per cent. of the world's oil supplies are obtained. Natural oil stores are usually tapped by means of the drill, and the oil then comes to the surface either by its own gaseous pressure through the drill hole or with the help of the lift pump. This method must remain the only one for the deep sources in most parts of the world, in spite of the fact that a serious percentage of the oil contained in the porous beds will never be extracted through drilled wells alone.

Mr. Barringer referred last year to the fact that the oil winner is one who bores, but M. de Chambrier has shown that boring is not always necessary, nor does it invariably bring about the best results. There are occurrences which lend themselves more to ordinary mining operations by means of shafts and galleries, and in view of the deadly nature of the gas special methods have had to be prepared. In the province of Alsace, as long ago as 1735



Monsieur PAUL DE CHAMBRIER,
Boverton Redwood Medallist, 1919-21.

UNIV. OF MICH.

underground work was started by the French miners, and was carried on without interruption until 1888, when complications set in and troubles began. Accidents occurred and the work became dangerous as well as expensive. Then M. de Chambrier and his associates stepped in and worked out a scheme which seemed to justify the expectation of success.

On the 15th February, 1921, the Council of the Institution accepted for publication M. de Chambrier's description of the new methods of working. Experience since that time has shown that the method has been very successful. Between 1921 and 1924 the production of crude oil in that district has been trebled, and galleries have now been extended to work a total length of something like thirty-four kilometres. It has also been shown that the operations are relatively safe—as safe as ordinary mining operations at any rate.

The great advantage of the new method is that it opens up stores that could never have been got at otherwise. It is possible that the new methods may be made applicable to other relatively shallow deposits, and that consequently resources now imperfectly exploited may be developed, with a resulting addition to our supplies of crude oil.

Everyone connected with the development of mineral resources must be conscious of the fact that the operations of the miner and the oil-driller are entirely of a destructive nature. The accumulated oil deposits are being destroyed as rapidly as it can possibly be done; for there are shareholders in a hurry to get their dividends. In most mining operations far more mineral is destroyed than is brought to the surface, and oil-drilling, at its best, results in leaving behind large proportions of the supplies which have been stored by nature, while few oilfields escape the destructive results of bad drilling. Every technologist, therefore, who does something which enables us to develop our resources to the full and to get out every drop of oil that can be extracted from the ground is adding to the value of our resources, and is in effect adding to the actuarial value of civilisation. The methods devised by M. de Chambrier and those who have been associated with him are of this beneficial class. The Council of the Institution, therefore, feels that it is justified in selecting as the first recipient of the Boverton Redwood Medal the author of the paper by which these improved methods have been made available to the petroleum world.

I have now great pleasure in inviting M. de Chambrier to come forward to receive the Medal which has been established in memory of our founder. We hope the advances that he has made in the technology of oil may spread to other fields before the driller has made it impossible to reap the full advantage gained by this great advance in oil technology. (Applause.)

**The President** then, amid applause, invested M. PAUL DE CHAMBRIER with the Boverton Redwood Medal.

**M. Paul de Chambrier** (speaking in French) said: Mr. President and Gentlemen, I am profoundly moved by the words which the President has been good enough to address to me, and I am greatly moved also at being honoured by receiving the Medal which your Institution is giving, for the first time that it has been awarded, to a foreigner. I would very much have liked to reply in the English language, but, unfortunately, I do not know English. I will, therefore, ask the President to be good enough to allow the Secretary of our Institution to read to you an English translation of the reply that I have prepared.

**Commander R. E. Stokes-Rees, R.N.** (Secretary), then read the following translation of M. de Chambrier's reply: Mr. President, Gentlemen and dear Colleagues, The kind words that our President has addressed to me, in the name of a scientific society with such a prestige as is enjoyed by the Institution of Petroleum Technologists, have profoundly moved me, and I thank you all very much. The genius of our former President, Sir Boverton Redwood, and the great work which he did in the science and industry of petroleum, have won the admiration of the world. I wish to be permitted to contribute my respectful homage to that great and noble savant.

I accept this testimony of your esteem with feelings of great emotion, and am considering it as a tribute rendered to workers, past and present, in connection with the Pechelbronn Mines.

In his posthumous work Sir Boverton Redwood mentions as one of the causes which might hinder the extraction of petroleum by drifts (*galeries*, as we term them) the accidents which had been caused by the discharge of gases during the past century. At the time he wrote his celebrated work Sir Boverton could not foresee the importance which the drainage system of the underground petroleum beds would later assume. But now, in view of the results obtained at Pechelbronn, he would be the first to proclaim the conquest over matter by this method of exploitation, by which we have been able, right in the heart of the petroleum bed itself, to get out the oil still charged with the gas which it holds. Whatever may be the nature of a conquest, it is never due to the initiative or the work of one single man. It would, therefore, be unjust to attribute the honour of it solely to one man only, especially as it has been a development of over one hundred years' continuity.

The energy, courage and perseverance of the first exploiters of the Pechelbronn Mines have been essential factors in the conquest in which we are engaged. For a century and a half the French family, Le Bel—with the aid of Messrs. Boussingault and Daubree—followed up the direct form of attack upon the petroleum

beds in question. At the commencement the upper strata, deprived of gas, permitted this form of working, but on penetrating gradually into the lower strata, the exploitation became increasingly difficult.

On account of the troubles encountered the Le Bels were obliged, in 1888, to abandon their method of underground extraction, but not without having made plans and documentary testimony of great value. It was after studying the Le Bel documents carefully that I arrived at the conclusion that extracting the oil by pumping was the cause of very great waste, as the greater part still remained in the ground. It can be well understood that realising such a considerable loss stimulated the thought of taking up, sooner or later, the extraction of sand, impregnated with the oil, from the greater depths. This important question was the subject of constant study on my part for many years before a practical solution was reached.

You, gentlemen and dear colleagues, who have awarded the Boverton Redwood Medal to one of your members, although he is not of your own nationality, will, I am certain, associate yourselves willingly with the homage that I wish to render to those "unknown warriors"—those Alsatian miners who were the first victims of the exploitation of the oil by underground working, and who fell bravely on "the field of honour."

But it still remained to make known amongst petroleum men the system of exploitation practised for the first time in Alsace; for the results are such as must interest the petroleum industry of the whole world. Major Albert Lautier, who was the Delegate in London in 1921 for the French "Essences and Petroles" Department, was quick to perceive the important rôle which the Institution of Petroleum Technologists could play in these circumstances—the authority of this Institution being practically the law in petroleum matters—and he had the good fortune to be able to induce the Council of the Institution to see the interest there would be, for British technicians in petroleum, in a description of the method of exploitation which had been referred to.

In nominating me for the Boverton Redwood Medal in recognition of the work which I had the honour of presenting to you—thanks to the initiative of Major Lautier—you have shown, on your part, the importance which you attach to the underground method of exploitation inaugurated by the French miners in 1735, practised by the Le Bel family for 150 years, and taken up again recently with all the advantage of modern technics. You have, in fact, drawn the attention of the scientific world and its technicians to a question which is bound to be greatly developed, and in doing that you have stimulated the zeal of investigators. Proud as I am to be the first recipient of the Redwood Medal for my work in connection with the more recent developments in the Pechelbronn method of

production, I desire to give the fullest credit to my colleagues at Pechelbronn for the great part they have taken in these developments. They, equally with myself, will always take pride in your generous recognition of this unique branch of petroleum technology which is particularly associated with France.

## "THE SERVICES."

**Dr. W. R. Ormandy, F.I.C., F.C.S., M.I.A.E.**, who proposed the toast of "The Services," said :—

Mr. President and Gentlemen, I feel highly honoured and much embarrassed by having to propose the toast which is down in my name. There are four Services, and it has been said that the Institution of Petroleum Technologists rather confines its attention, judging by the number of military, naval, and air guests that it has, to the fighting Services. I venture to think that the Civil Service should be considered in this connection.

We members of the Institution of Petroleum Technologists have many points of contact with the Services. It is quite wrong that we should be thought to be a belligerent class of people. I think we recognise that our first duty and our first service is to the Civil Service and to the ordinary body of humanity which is represented by them, because they are the largest users of oil. The work which is done in the development of the utilisation of oil and in the development of the engines which utilise it is done chiefly and primarily for the benefit of the civil population. The advances and improvements which are made undoubtedly redound to the benefit of the Services, but in the first place I think it is undoubted that help is chiefly directed to the Civil Service.

The Civil Service, I think, acts as a very efficient buffer between us, the body of the people, and Parliament. It has been said of politicians that they are people of few rules and no principles. (Laughter.) I think we might say of the Civil Service that they have too many rules, but we are proud of the fact that they have very high principles. (Hear, hear.)

With regard to the belligerent Services, if I may call them that, they consist of the Navy, the Army and the Air Force. Some of us may, I imagine, be inclined to think that the latter, which is the youngest of the three, will shortly be the most important. (Hear, hear.) We may be inclined to think also that they have not received and do not receive that consideration by the Government which the services they may render to us in time of necessity deserve and require. I sometimes think that those connected with the Air Service, when they look at the amount of money which is allocated to them and compare it with the amount allocated

to the other Services, must think of an old Turkish saying. The Turks believe that our Lord was a very great and a very religious man, and they have a story that our Lord once visited the Bosphorus and remained there a month, and he had with him a Frenchman, a Greek and an Armenian. At the end of the month, when he was going away, he granted each of them a wish, but each had to wish separately, and no two of them could wish the same thing. The Frenchman's turn came first, and he wished for glory. The Greek wished for money, but when the turn of the Armenian came, he said, "I suppose it is too late to wish for money?" He was told it was. There was a long pause, and then he said, "I would like some knowledge." The Turkish story says that our Lord was immensely pleased with this, and said, "What particular knowledge would you like?" The Armenian replied, "I would like to know which of them got the money." (Laughter.) I think that must be the feeling of the Air Board when they compare the amount of money which they get with what is given to the other Services.

My duties take me very frequently to Geneva, and I have met, though not officially, quite a number of interesting people in the cafés of Geneva who may be regarded as enthusiasts, and possibly —indeed probably—as somewhat unbalanced enthusiasts. There is no more dangerous wild fowl in this world than the unbalanced idealist. If we look back on history, as it is useful that we should occasionally, and go back to the oldest historical times and examine the history of the old Pharaohs, we come to the XVIII Dynasty, when the Pharaohs had probably achieved the greatest height the Egyptians ever reached, and when their Empire stretched from the Amanus mountains to the mountains of Armenia and into Persia. At that period a king who was distinctly before his time came to reign over Egypt. Had he been born yesterday he would yet be before his time. He regarded it as wrong that people should fight. He believed in turning the other cheek when one was smitten. Unfortunately, it was discovered that not only was the other cheek hit, but he got it in the neck badly as well. (Laughter.) The history of that king marks the absolute decadence of the Egyptian Dynasty; they became people of little importance. To-day I feel that all of us are proud that we have the Services between us and those idealists who believe there is a possibility of universal peace. The thing that alters least in this world, less than the great mountain ranges, is human nature, and I for one—and I feel I am speaking for many of you—am proud that we have the fighting Services between us and those who would leave us at the mercy of the unbalanced idealist.

I ask you, therefore, to join with me in drinking the health of

"The Services," coupled with the name of Air Vice-Marshal Sir W. Geoffrey Salmond. (Applause.)

The toast was duly honoured.

**Air Vice-Marshal Sir W. Geoffrey Salmond, K.C.M.G., C.B., D.S.O.:** It is a great honour to me to reply, on behalf of "The Services," to the toast proposed by Dr. Ormandy. He has mentioned the Civil Service. We of the Services admire the Civil Service, and are proud that we are so closely associated with it.

It is needless of me to accentuate the importance of oil fuel to the Services. So important is it that directly a time of stress arises we have to appoint authorities to ladle it out to us. You have heard, I daresay, in times gone by, and indeed in recent times, that air power has revolutionised war. I would like to point out that air power rests on oil fuel, and the only one of the fighting Services which can at present conserve oil fuel is the Royal Navy. I do not say this because I want to throw oil fuel on troubled waters, because those troubled waters do not really exist, though they do exist, very often, in the columns of the Press. Since we depend so much on the Royal Navy—and on no greater service could we depend for our efficiency—it by no means detracts from the desirability of doing our utmost to try and solve the problem of home fuel supplies, and we rely on you, gentlemen, in this matter.

Although you are of enormous assistance to us, in my capacity as Air Member for Supply and Research, I sometimes think that you give us a great deal of work. For instance, the great danger in my own Service is the danger of fire. Fire is a very great danger which is constantly before us, and which we have to do our utmost to overcome. The danger of fire if an aeroplane crashes is enormous, and the results, as we all know, are terrible. That leads us and has led us to the investigation of heavy oil for compression ignition engines. We have gone a long way in that direction already, and although we have not actually had an aircraft in the air flying under these conditions, we are on the verge of it. I hope this year we shall accomplish that. That will make an enormous difference, I hope, to civil aviation and to our Service aviation.

Apart from that there is the question of detonation trouble in high compression engines. We are actively pursuing the question of how this can be overcome, but amongst all the remedies we have applied we have met with most success with that glorious old remedy alcohol. (Laughter.) After this dinner to-night I think the Services can rely on the Institution of Petroleum Technologists with renewed confidence. (Laughter.) I therefore thank you

very much on behalf of the Services for the very kind toast you have accorded us. (Applause.)

## "THE PETROLEUM INDUSTRY."

**Sir Robert Burton Chadwick, M.P.**, who proposed the toast of "The Petroleum Industry," said :—

When Sir Frederick Black honoured me a few days ago by asking me to propose the toast of "The Petroleum Industry" this evening, I happened to read in my paper a wonderful account of a great achievement by some of our astronomers—or astronomical technologists, as perhaps I should call them—who announced to the world that they had been able to measure the diameter of a star of the third dimension so far distant from us that its light reached us only after 120 years, travelling at the rate of six million million miles a year. That may sound a little far from the toast to which I am speaking. (Laughter.) Incidentally, these gentlemen find that this speck is some hundreds of times the size of this world. If now and again astronomical technologists or the electrical technologists present to the mind of the layman these paralysing dimensions as the result of their research, and the average layman sometimes stops to ponder over them, the result is—at any rate, in my case—that his mind becomes numbed, which is perhaps as well, for if it did not one might go mad. It is under that influence, under the influence of that incident, that I find myself in a relatively humble condition of crushed insignificance now that I am about to propose the toast of "The Petroleum Industry," which is the biggest thing, as an industry, that we know in the world to-day. ("Hear, hear.")

It is one of the inherent drawbacks in the life of a politician that he has to talk a great deal, very often on subjects of which he knows something—(laughter)—but very often on subjects of which he knows little, but about which he pretends to know much. His agility meets its supreme test when he finds himself having to talk on a subject about which he knows nothing to an audience which knows everything about it. To-night, therefore, in the very few remarks I am going to make, I will only speak of the petroleum industry in a very general way, and I will naturally speak of it as it presents itself to the lay mind in the great effect it has on the politics of the world, and of the tremendous world force implied by that expression, "Petroleum Industry."

I suppose, Sir, it is true to say that oil and the possession of oil is one of the greatest factors in world politics to-day. From Alaska to Tierra del Fuego in America, from Western Europe to Japan and Formosa, this wonderful element is being produced in greater and greater quantities and is revolutionising and transforming the

whole of the transport and distribution of the world. The development and the use of oil in its effect on humanity has been more rapid and more important, probably, than the development of any other industry in history—one might almost say not excepting steam and electricity. I do not think that is putting it too high. One of the most remarkable features of it is that this terrific power is under the control only of a very few great commercial corporations, corporations which are almost as powerful as Governments.

I suppose it is right to say that of all commodities oil sells itself, because the world is always demanding more. I think it was Lord Curzon who said that the Allied Armies floated to victory on a great wave of oil. As I mention Lord Curzon's name, I am sure it will meet with your approval if, on your behalf, I say how cordially our hearts go out to him at this moment in sympathy, and how anxiously we hope that he may be speedily restored to health. (Applause.) Lord Curzon is a man who has done much for the development of the oil industry.

We are all able to judge best on a matter of this kind from our own particular standpoint. My business, before I became a politician, was the business of shipping. I am able to say that I can drive my 8,000-ton cargo ship through the water at a rate of 10 knots an hour on a consumption of something like 6 or 7 tons of oil, whereas it would take me 32 to 35 or more tons of coal to do the same work. That is probably more markedly expressed in other industries.

In your company, gentlemen, I find myself in a strange atmosphere. As a representative of the Board of Trade, I am frequently called upon to speak about trade, and honestly I cannot for the life of me see that there is any very definite indication of an improvement in our trade. I suppose that the petroleum industry feels, to a certain extent, the fluctuations of trade in general, although I judge that in the case of the petroleum industry it is merely a difference between greater and lesser profits that you feel, and not, as in other industries, the difference between profit and loss. As I have the honour to represent the Board of Trade, however, I should like to conclude by saying a word or two on trade and industry, because I am perfectly sure that all you gentlemen here to-night are affected to some degree by the state of trade and industry. Frankly, I say, I do not think one can honestly state that there is any definite improvement in our trade outlook at the moment. I am convinced that we are in for a sweeping tide of competition industrially, and in regard to trade, such as we have never known before in history. Nevertheless, I am more encouraged to-day than I have been for years, and that encouragement arises from two totally different circumstances. The other day, as I sat in the House of Commons listening to Mr. Stanley Baldwin

making a very great speech on industrialism, it was borne in on me that England had been blessed again with a great leader at a moment when she needed him most. (Applause.) The other circumstance—and you may wonder why I combine two circumstances apparently so remote—is that I am profoundly glad that Sir Frederick Lewis has given an order for five motor ships to a German yard. I will tell you why. I believe that the combination of those two circumstances will have a most profound effect upon our country. I am perfectly sure that that latter circumstance has startled the British nation more than anything has startled it since August, 1914. I do not know how closely it comes home to you who are petroleum technologists, but I imagine it touches your fairly closely. I believe that the effect of that danger signal to our industry will be relatively as great as the danger signal which brought the country so remarkably into line in August, 1914.

Coincident with that awakening we have discovered a great leader whose wise utterances must be appealing—as I know and you know they are appealing—to the best that is in all men in this country, irrespective of their political faith. ("Hear, hear.") We have a man who, by his life's experience, is peculiarly fitted to understand these great industrial questions—a simple, human, strong man who, out of the fullness of his heart, on the occasion of which I am speaking was able to conclude with the utmost dignity one of the most remarkable speeches ever made in the House of Commons, with the simple prayer, "Give peace in our time, Oh Lord." ("Hear, hear.")

Gentlemen, those two circumstances, combined with what I think is of great value—the hope of a period of political peace—give me cause to say that I am more encouraged than I have been for many years. It is with the utmost cordiality and enthusiasm that I give you the toast of "The Petroleum Industry," coupled with the name of my old friend and my old Chief, Sir Frederick Black. (Applause.)

The toast was enthusiastically received.

**Sir Frederick W. Black, K.C.B.**, who responded, said:—

I should like to express my grateful thanks to the two speakers who have alluded in complimentary terms to what the Civil Service does for the country. In the next place, I should like to say how much certain things which Sir Robert Burton Chadwick has said have gone direct to my heart. He has been very kind indeed in referring to an old fellow like myself as having been his "Chief," as I was in the days of the Ministry of Munitions. The positions are now reversed, and whatever else may be the sentiments of a Civil servant, he has the greatest respect for those Parliamentary Chiefs who benefit by his good suggestions and take all the blame

for his bad ones. (Laughter.) I remember Sir Burton Chadwick, in the Ministry of Munitions, before the Ministry of Shipping was formed, had one of the most difficult duties to perform. He had the control of the bringing in of all the supplies from overseas, and sometimes he found that luxuries were coming in which contended with necessities like munitions. He never hesitated then to tell his colleagues and the public, incurring perhaps a certain amount of opprobrium by so doing, that there were little luxuries that must be done without. On one occasion he wrote a letter to the *Times* telling the ladies of England that they must even forgo an occasional cup of tea. He came into my office one afternoon when I was having a cup of tea and a biscuit, and I said, "I suppose you will stop me?" He replied, "Not exactly, but I advise you to set a better example." (Laughter.) I read the other day a speech by a man who was in charge of the advertising and propaganda department of an American Oil Company. He said complaints came to his directors that the results obtained from the products of the Company were not entirely in accordance with what the advertisements suggested they would be, and he was told that he must tone down his advertisements in consequence. He said, "I am not going to tone down my advertisements. My job is to keep up an ideal a little bit ahead of you practical men; your job is to tone your performances up to my high ideals." I believe this body of experts, if I were to paint too beautiful a picture of what the petroleum industry is doing, could tone up or down the colours in any way they pleased; but when they had done that, this would remain: the petroleum industry to-day is performing some of the most important and essential services for mankind with high efficiency and at a relatively low cost.

I am going to say a little more presently on the subject of costs, but first let me point for a moment to what I may call the "barometer" of the petroleum industry. Very briefly I think we may say that, variable as it is from time to time, it looks a little steadier at the moment than it has been, perhaps, for some time past. I am referring to the relation between production and requirements, which I think is now on a more stable basis. Over-production seems to be, to some extent, in hand. You can get this at a glance if you look at certain figures. The world's production of crude oil in the year 1923 was 137,560,000 tons. The figure for 1924, though perhaps it has not been exactly ascertained at the moment, is about 137,642,000 tons. Generally, you get a rise of from 10 to 15 per cent. from year to year, but the fact that those figures are so near together points, I think, to some control over the over-production which recently prevailed.

On the subject of prices I want to draw your attention to some figures which are widely posted in the Underground Railway

stations. The London General Omnibus Company says that the fares for 40 days in each year, one-ninth of their total receipts, or 11 per cent., are spent on petrol: 220 days' fares, eleven-eighteenths of the total receipts, or 57½ per cent., are spent on labour. I am not suggesting that the latter figure is too high; I merely suggest to you that, at any rate, the petroleum industry "does its bit" with considerable regard to economy.

We have had some very welcome testimony from Sir Burton Chadwick as to the economy of fuel oil in Diesel-engined ships. I believe that shipowners generally would say that the proportion of the working costs of such ships due to the oil fuel bill is comparatively reasonable. I believe our Navy experts here to-night could tell a similar story of the Navy, which is now, I suppose, between 95 and 100 per cent. oil-burning, mainly under boilers.

Let me give you one other example, of a rather trivial nature you may think. In the days of ancient Rome there was a poet who said that "black care rode behind the horseman." You can imagine that if you were always to carry a passenger like that you would grouse a bit at the cost of hay and beans, or whatever they fed horses on in ancient Rome. If you take the case of the young motor cyclist, however, who to-day takes a young lady, whom the newspapers describe as "Phyllis of the Pillion"—(laughter)—for a ride, say, to Brighton, and reflect that with petrol at 1s. 6½d. a gallon he can take her there and back at a lower price for petrol than her lunch and chocolates and cigarettes will cost him, I suggest to you—and those of you who are young will bear me out—(laughter)—that he has not much to complain of. There is not much pleasure in watching a girl eating chocolates and smoking cigarettes, but the thrills you can get with a pair of soft arms around you—(Applause)—and the trustful confidence placed, or very often misplaced—(laughter)—in your skill as a driver—well, the man who would grouse at the price of petrol after that . . . . —(laughter). It is unnecessary to finish the sentence. (Laughter.) I am convinced that if we could put Phyllis and the motor-cycle back into those ancient days the two young people, instead of grousing at the price of petrol would hang up in the shrines of Venus and Minerva pictures of every petroleum technologist from Colonel Drake to Sir Thomas Holland. (Laughter.) There are things in the services performed by petrol that cannot be expressed by figures in a balance-sheet. I refer particularly to the health and facilities that come to the community from omnibus and charabanc services, especially from the great towns to the country.

In previous years we have heard Admiral Sir Robert Dixon talk about heavy oil fuel for the Navy, and we have heard to-night what the Air Department thinks of petrol. We all welcome Sir

Sefton Brancker back after his great aircraft trip to the East, and we wish good-luck to those two Cabinet Ministers who are going to trust themselves in an aircraft across the Desert in a week or two.

I should like next to say a word about the oil geologist. He is a very modest fellow. He never claims to be infallible. All he says is that he has greatly reduced the percentage of "dry holes"—the percentage of errors. I read the other day, in a paper presented at Wembley last June by Sir Robert Waley Cohen, of a geologist who said that if he could get dead right every time he recommended putting down a drill, he would not be advising an oil company, but exploiting oil on his own account. (Laughter.) The point has been put in a different way by a member of this Institution, Mr. De Golyer, in a recent speech in America, who said: "If we could be right all the time we should knock the bottom out of the oil market; prices would go down enormously." I suggest that, in addition to that, it would not be long before the world's oil supply would be exhausted. I seriously think, therefore, we should be thankful to Providence that the mantle of infallibility has not yet descended on the shoulders of any geologist, not even on those of the distinguished ornament of that science and profession who sits in our Presidential Chair.

Something must now be said about the efficiency in use and in marketing which has been brought about by chemists and engineers. It is no new story to experts in petroleum technology that the demand for motor spirit or petrol during the last fifteen years could never have been met from the same proportion of crude oil as was used to meet it under the ordinary methods. If it had not been for the use made of petrol from natural gas—the wet gases, including casing-head gas and from "cracking"—the present requirement could only have been met from a vastly increased production of crude oil; otherwise prohibitive prices would have checked demand. As you know, when oil technologists talk of "cracking" processes, they recognise that motor spirit is then obtained at the expense of the fuel oil; but this leads really to a more economical use of natural resources, because lower grades of crude can be brought in for heavy fuel oil purposes. We have had figures given us as to the economical use of fuel oil from what I think Sir Westcott Abel the other day called the "Dieselisation of the ocean." The efforts of petroleum refiners and of engine builders have been moving together for efficiency and for lower fuel prices.

Having referred to technical achievements, I looked over the current number of the Journal of the Institution to see whether any minor failure had to be recorded, and I found, as I should expect from the conspicuous honesty of our technologists, that one failure is recorded during the year. Great efforts have been made

to get food products out of petroleum oil, but so far without commercial success, in spite of the use in the experiments of "a plentiful supply of air and of molybdenum and uranium oxides as catalysts."

Last, gentlemen, but not least, a word about the commercial men who direct the oil companies and the capitalists who venture their money in a great speculative industry. Altogether, I see that the figure of capital in the American oil industry is usually put at something like 1600 million pounds. I do not know the world's total exactly, but it must be getting somewhere near 2000 million pounds or thereabouts at the present moment. Much of that capital is represented by assets like oil wells, concessions and leases. A large proportion of the total capital, perhaps 500 millions sterling is invested in refineries and marketing equipment; about 100 millions may be in pipe-lines and, say, another 100 millions in tank steamers. One can well understand that when a prophet gets up and says, "The oil wells of America will be dry in twelve or fifteen years," some concern is naturally felt. I have read recently some speeches made at a big oil Congress in America. One speaker, with large interests and experience in oil, said that he took a far more optimistic view of the world's petroleum resources, including shale. Another speaker, reviewing the financial situation, remarked that, to the usual threefold category of untruthful persons (he used a stronger word; he said "liars")—(laughter)—would have to be added a fourth and special class for pessimistic oil prophets. He did not say where he would locate the oil prophets if they prophesied smooth things and prosperity. I suggest they would be then too good for this mundane sphere, and there is no classification to which they could be assigned. The speaker referred to made an appeal to the petroleum technologists of the world to go out and find new oil pools. I do not know whether he was thinking of Mesopotamia in particular, or some other part of the world. He begged them to find new supplies; and he very properly talked about their courage, their initiative and resource. He asked them to keep the oil supplies of the world going until substitutes were found. Knowing something of the petroleum technologists in America and those of this country, as I think I do, I should not think it very necessary to make such an appeal. They are doing these things all the time, and they will continue to do them as far as is humanly possible.

One word more. When I was a boy I once had to write an essay on the subject of "The world knows nothing of its greatest men." In those days there was no Institution of Petroleum Technologists, and I did not know that such a profession existed. To-day if I had to write that essay over again I should draw some of my principal illustrations from the petroleum industry, which is your industry and mine also. (Applause.)

## "THE INSTITUTION OF PETROLEUM TECHNOLOGISTS AND THE PRESIDENT."

**Mr. Francis E. Powell,** who proposed the toast of "The Institution of Petroleum Technologists and the President," said :—

I am very glad to be with you again to-night, and I am particularly proud to be called on to propose this toast. In looking over the records of this Institution, I notice that its progress is continuous and very praiseworthy. I notice particularly that the student body is increasing in numbers, and that the Students' Section is doing excellent work. I notice also that you have been giving some Student Scholarships. All this speaks very well for the future of the Institution, and is to the credit of those who have charge of that branch of your work.

There is one other little activity which you seem to have indulged in, which I read about the other day, and which I am not quite so sure about. You had before you for demonstration what was called a petrol diviner—a new type of instrument designed to discover petroleum or other minerals in the ground. I do not know how a thing like that works, but if you want to see a genuine petrol diviner, stop by one of "Sonney Prattkins" golden pumps and you will see it produce petrol from the ground in the most miraculous manner. (Laughter.)

The petroleum industry is of primary importance, and we must appeal to you who belong to the technical engineering fraternity to conserve the production of oil and to keep this industry on a profitable basis. America is still producing about two-thirds of the world's supply. Other countries, like Persia, Rumania, Mexico and latterly Russia, contribute the not insignificant balance. I speak more of America, because that is the country I know most about, and I will give you a few figures to supplement those given by my friend Sir Frederick Black.

In 1923 America produced 739,000,000 barrels of oil. In 1924 721,000,000 barrels were produced, and the estimate for 1925 is 700,000,000 barrels. In 1924 we had 17,730,000 motor vehicles in the United States, which consumed 186,000,000 barrels of gasoline. In 1925 they will consume 240,000,000 barrels. The rest of the world is progressing on the same lines.

Where is all this production to come from ? So insistent is the cry for conservation in America to-day, so pressing is the need for this conservation, that President Coolidge has appointed a Commission called the Federal Oil Board to go into the matter, and its appointment has the approval of the entire industry. This Commission addressed a series of questions dealing with vital technical problems to the refiners of the country, and amongst these problems were the recovery of oil from the deep sands,

improved refining processes and cracking processes, the yield of the by-products of petroleum, the conservation and use of fuel and the increased production of lubricating oil. All these are vital questions.

As to production, no man or body of men would attempt to develop a petroleum proposition to-day without first having the area and all connected with it reported upon by a competent geologist—someone who is familiar with the ground and who will know what chances there are from production there. In no other way can the hazards of " wild catting " be guarded against.

As to cracking processes, out of 574 refineries in the United States more than one-third to-day are utilising some form of cracking process. Last year they consumed a little over 3,000,000 barrels of oil per day, and during the year produced 213,000,000 barrels of gasoline. That was a very large output indeed, but the most significant fact—and one touched on also by Sir Frederick Black —is that if that had been produced ten years ago—that is to say in 1914—it would have taken two and a half times as much crude oil to have achieved the same result. That is where the technologist, the chemical engineer and the refiner have contributed to what would otherwise have been a shortage when the producer of crude oil could have by no means coped with the situation.

Sir Frederick Black has given you figures representing an investment of over £2,000,000,000 sterling in the industry throughout the world—also protected by this very great achievement.

This performance on the part of the refiners, which is one of the wonders of the world, really, is not the only thing that must be done to obtain increased recovery from the crude petroleum. There must also be economy in steam, in chemicals, in fuel, in equipment, and in all those things that go to make up the refining industry.

Some of you older men may remember the name of Frasch. Years ago Frasch, who as a chemist in America was doing research experiments in his little Canadian refinery, discovered how to desulphurise Lima crude oil. He did this at a time when the standard oil refiners had failed to solve the problem. Frasch told me he went to New York and met a Committee there on which was Mr. Charles Pratt, the veteran refiner, who was rather a religious man, and he said to him, "I do not believe you have ever done it. I do not believe the Almighty ever intended Lima crude oil should be refined." Frasch replied, " I do not know what the Almighty intended, but I have done it." (Laughter.) So he had ; he had solved the problem, and at a time when the older fields of Pennsylvania were fast becoming exhausted. He saved the situation.

What we want in this industry is new, useful and accurate information on the production, manufacture and marketing of oil. Here is a chance for the technologists, for scientific refiners and for anyone who wants to put his back into the business. If we can accomplish this, if we can get these things done, it means a very great deal to our industry, and I think it is worthy of the very best efforts of those who are engaged in it.

Now I come to another side of the industry which perhaps interests the younger members more particularly, and that is its "Spirit of Adventure." The spirit of adventure is something which keeps the heart young and the faculties ever on the alert. It is very fascinating; it brings great rewards. Men who are always content to remain in the same little corner of the world in which they are located, and who never take advantage of their opportunities to travel round the world and improve their minds and memories with impressions of life-giving interest, have no ambition; they do not know what the spirit of adventure means. He who has that spirit, on the other hand, need never grow old, for if his plan of life is well balanced and he enjoys his life as an absorbing game, his heart will always remain young, and youthfulness of heart brings keenness of sympathy. (Applause.)

And so, Mr. President, I come back to where I started—sympathy with the technical and engineering side of the petroleum industry. It gives me great pleasure therefore to wish this Society future success and prosperity. I give you the toast of the great future of the Institution of Petroleum Technologists, coupled with the name of your President.

The toast was received with acclamation.

**The President** (Sir Thomas H. Holland, K.C.S.I., K.C.I.E., D.Sc., F.R.S.):—I thank you on behalf of the Institution for the very kind way in which you have received the toast proposed by a very constant friend of the Institution.

On behalf of the Council, it is the duty of the President to account for ourselves for the year to our shareholders, as it were—the members and the guests who honour us with their presence at our dinner. The geological members of the Institution have been referred to with a certain suggestion of doubt by some of the speakers this evening. It is true that they are often happier when they are prophetic than when they are historical, for in dealing with oil occurrences the geologist, like a very ardent lover, often finds that realisation does not verify his anticipations. (Laughter.) At any rate, that is what other oil technologists say. On this occasion, as a geological member of the Institution, I have an easy task in accounting for ourselves during the past year, as during

that year the Institution was under the administrative care of Mr. Barringer. (Applause.)

Last year Mr. Barringer from this chair alluded to the progress which the Institution had made during his first term of office. I can tell you with confidence that that progress has been maintained in a most satisfactory way during his second term of office, in regard to membership, finance and output of work. During the past year we have turned out seven parts of the Journal containing over 900 pages of original papers and over 400 pages of abstracts. The results, I think, indicate a very satisfactory activity on the part of the members, and they must have cast a very heavy burden indeed on our conscientious Honorary Editor, Dr. A. E. Dunstan, to whom the very special thanks of the Institution are due. (Applause.)

At the last Annual Dinner, Mr. Barringer referred to a number of special developments which had been inaugurated during the previous session. There was the completion of the work of the Standardisation Committee, the proposal to hold an Empire Mining and Metallurgical Congress at Wembley, the occupation by the Institution of new quarters, and the inauguration of two Students' Sections. During the year that has just passed there were no startling incidents of that kind, nothing of the sort that the evening papers might describe as "dramatic"; but there has been something very much better—the new features have been consolidated and have moved forward successfully. The report of the Standardisation Committee has been published, and the heavy demand for it shows that its value is understood by the technological community outside. The Empire Congress at Wembley, under the Presidency of Lord Long, was, I think, a distinct success, and in that work we had the co-operation of four or five other technical Institutions. The new quarters which we have entered into at Bedford Street give us now room for members to use their library and reading-room, and I think there is no doubt at all that they are satisfactory, as the Secretary has never grumbled once, although he is a naval officer. (Laughter.)

The progress of the Students' Section deserves special notice, and I am glad that Mr. Powell has called attention to it. It was through the generosity of the great company with which Mr. Powell is associated that we were able to institute two scholarships at South Kensington and Birmingham. (Applause.) Both the London and the Birmingham branches have been marked by a real interest on the part of the students, and some of the older members are even jealous of the high quality of the papers and discussions which have been held at the meetings. The paper by Mr. Blakiston on the Rumanian oilfields, which was read last year and published in the Journal last November, was the one selected by the Council for the

medal and prize of the Institution. As the head of the principal competing College, I offer my unreserved congratulations to Birmingham University. (Applause.) I should also like to utter this small warning, that if the medal and prize go again to the Midlands the competition will have risen very satisfactorily. We are indebted very much indeed to Mr. Powell for starting the scholarships, and we are also indebted to Lord Cowdray for his very generous contributions to the expenses of the Students' Sections. (Applause.) Those of us who are senior in years and full members of the Institution realise the value of Students' Sections. We know that through them the Institution is going to grow in a healthy way and be consolidated for future use.

I have a very lively recollection of the day—it was after lunch, of course—when Sir Boverton Redwood suggested that we ought to do something to form an Institution to gather together the three species of witnesses who came before us when we were both members of Lord Fisher's Royal Commission on Naval Fuel. We have heard a great deal at these Annual Dinners as to how much the Navy owes to oil. I am not quite sure if the younger members of the Institution realise that the Institution itself is the baby of the Navy. (Applause.) We then realised that the all-round technologist could never live again. Sir Boverton Redwood himself was about the only one who could at that time combine an intelligent appreciation of all the various phases of oil winning, of oil refining, and of transport and consumption. No one was more conscious, however, than he was that the day for specialisation had arrived. There was, he knew, a danger that we should drift apart, each one interested in his own community and his own particular technical specialisation. With that remarkable prevision which always characterised his thoughts, he saw the necessity of forming some organisation which would secure the co-operation of the geologist—perhaps I may be allowed to put him first now—the chemist and the mechanical engineer.

These three had apparently nothing in common except their interest in the development of oil. There were some who thought that the organic union of the three groups of technical specialists, so utterly unlike in nature, could not be effected, but Sir Boverton Redwood said: "It is not the like but the unlike chemical elements that show strong chemical affinity and make a stable compound." ("Hear, hear.") His forecast has been abundantly verified. We are a very happy family in spite of what might be thought from the remarks which pass between Dr. Ormandy and myself. (Laughter.) Whether the result is due to unity of purpose or to the fact that we are unable critically to judge one another I am not quite certain. (Laughter.) I agree with Mr. Barringer in regarding his predecessor as a great chemist. Prof. Brame and I are in perfect agreement

in regarding Mr. Barringer as an eminent engineer. It is possible that my two predecessors may say—whatever they think in their minds—that I am a geologist. (Laughter.) In that way we live together as a happy family.

At any rate, the trinity of specialists makes a very good working machine. It grows in size and it grows in the output of its literary products. We have the monthly satisfaction—those of us who are now installed as members—of rejecting candidates that do not in our opinion come up to the standard which our distinguished founder hoped we should maintain. ("Hear, hear.")

My colleagues on the Council agree, I am sure, that our success is largely due to the great and very generous support that we get from those who are taking a leading part in the commercial development of oil. The leading companies welcome the standardisation of oil products and oil apparatus, and they have shown their readiness to support our efforts in dealing with the much more difficult problem of standardising the oil expert. I have, therefore, on behalf of the Council, to thank you very much, Mr. Powell, for the kind way in which you have proposed the health of the Institution, and all of you, gentlemen, for the way in which you have received it. In doing so, I should like to say how much those of us who hold positions which are more ornamental than useful on the Council realise the great value of the work which has been done during the year by our Secretary, Commander R. E. Stokes-Rees, R.N.—(applause)—and by his staff. I have mentioned Dr. A. E. Dunstan, and I should like to mention our Honorary Secretary, Mr. Arthur W. Eastlake—(applause)—who has been with us since the foundation. I should like to mention especially one gentleman who is unfortunately absent to-night on account of illness. I have just received a telegram from him. I refer to the Chairman of the Finance Committee, Mr. A. C. Adams. (Applause.)

## "OUR GUESTS."

**Prof. J. S. S. Brame, F.I.C., F.C.S.,** who proposed the toast of "Our Guests," said:—

The toast of "Our Guests" is one of the most delightful of toasts, and I have the honour to-night to propose it. It is delightful as a toast because it breathes the spirit of hospitality, the spirit of good fellowship and with us, so frequently, it means a revival of old acquaintanceships. Many of our guests to-night are old friends of the Institution whom we delight to welcome once more. I need hardly refer to them personally, but amongst them we have Engineer Vice-Admiral Sir Robert Dixon, K.C.B.—(applause)—Air Vice-Marshal Sir Geoffrey Salmond, K.C.M.G.—(applause)—and I am

sure everyone is delighted to see our real veteran Admiral Stokes-Rees, C.B., with us again to-night. (Applause.)

Some of our guests are here for the first time, and we are particularly glad to welcome M. Paul de Chambrier, who has received the Redwood Medal to-night. (Applause.) He is our guest, and we are proud indeed to have him as a Member of the Institution. Another Member of the Institution whom I am sure we all welcome is our old friend, Major J. A. Lautier. (Applause.) Further, we have heard mention to-night of the names of two gentlemen who have gained the Institution Scholarships at the Imperial College and at Birmingham University—Mr. Ernest Clark and Mr. Geoffrey Cotton. (Applause.) I am sure we extend the heartiest possible welcome to these two gentlemen.

I should also like, on behalf of the Institution, to extend our welcome to Mr. Douglas Vickers. (Applause.) His name is so well known in connection with the great firm of Vickers, Ltd., that we are all quite familiar with the work which he has done, and we realise to-day that, in a way, Mr. Vickers has become a petroleum technologist in that his great firm in these peaceful times is diverting some of its activities from the boring of guns to the manufacture of boring material for petroleum.

We have also many personal friends here to-night—personal guests—and to all such gentlemen we offer a hearty welcome. We trust we have proved so successful as hosts that visitors will all hope we shall ask them to come again. ("Hear, hear,")

We have received two disappointments in that we have had apologies for unavoidable absence from the Prime Minister and from Mr. Winston Churchill. We can only hope that at some future date their Parliamentary activities will not be quite so onerous, and that they will be able to accept the invitations which issue from the Institution.

This toast is a most delightful one for its proposer, because there is so little that need be said in commendation of it. I might almost put it in the same way that we put the toast of His Majesty—"Gentlemen, the guests." The less a proposer has to say the more time it leaves for the gentleman responding to the toast, and at this late hour I do not wish to stand between a guest and those who are anxious to hear him.

To-night the response is to be made by Dr. J. W. Evans, the President of the Geological Society. Petroleum location, petroleum production, petroleum refining and distribution call for experts of widely varying character and attainments. I cannot think of any other Institution whose membership is necessarily so heterogeneous as is the Membership of this Institution, but we are not jacks-of-all-

trades. We have jacks of sundry trades, it is true. As Sir Thomas Holland has indicated to us, we have the engineer, the chemist, the chemical engineer—a much criticised term—and we have the geologist. I might say, also, we have the financier. Whatever our own special link in the complete chain of petroleum technology may be, we all realise that the first link in that long chain between the discovery of oil and the marketing of the finished product is the geologist. It is therefore with the very greatest pleasure that we welcome the President of the Geological Society here to-night, and it is most appropriate that I am able to couple with this toast the name of Dr. J. W. Evans, C.B.E., F.R.S., President of the Geological Society. (Applause.)

The toast was then honoured.

**Dr. J. W. Evans, C.B.E., F.R.S.** who responded, said: When I read the list of the distinguished guests who are present this evening, I felt that you, Mr. President, had laid a very heavy responsibility upon me, a responsibility which is all the heavier in that I must confess that I have never had any very close connection with the oil industry or with oil technology. As an economic geologist, of course, I am interested in every kind of mineral product which is exploited for the uses of humanity or profit, but I must acknowledge that when Sir John Cadman and I were the joint advisers to the Colonial Office with regard to minerals, coal and petroleum were allotted to Sir John Cadman, and the rest to myself. (Laughter.) I take it there is no-one here who is interested in the "rest," except, of course, your President and the President of the Institution of Mining and Metallurgy.

Although I cannot pretend to be an authority in regard to anything connected with oil, I have at any rate prospected for oil, but, I am sorry to say, with a conspicuous want of success. I remember when I was doing geological work in the Andes some half-caste came to me and said there was an oil locality away in the mountains. I and those with me toiled up a dry mountain torrent. We did wonders in the way of gymnastics in getting up where the waterfalls were when the river was in flood, and finally we reached an admirable little valley, quite a picturesque place, but I could not see the slightest trace of oil, so we came back very disappointed. I remember another time when I was travelling through the Andes I was told of a place where there was a considerable amount of oil seepage. At last we got there, but unfortunately it had been raining heavily for some time, and I saw a great flowing river rushing past, and was told that if only this river were dry I should at once see a most interesting oil occurrence. Whether anyone else has been to this spot and succeeded in getting oil I do not know.

Geologists as a whole, of course, are very grateful indeed to the oil industry. It has spread a certain amount of geological knowledge throughout the financial world. I do not suppose there is anyone in the City who does not know, or think he knows, what an anticline is. Then again, we get a certain amount of information from oil exploitation, though not as much as we wish, because many geologists engaged in the work are sworn to secrecy. My own opinion is that at any rate they should keep careful records, and when enough time has elapsed to make it safe to publish the work they have done they should make a point of doing so. Another thing I should like to see is the use of boring plant that yields cores. They give so much more valuable information than the pulverised material usually obtained. I know it costs more than the usual method of sinking oil wells, but I think the Government might very well give a subsidy to cover the difference. There are some oil seekers, of course, which seem to have devoted themselves more to finding geological knowledge than to finding oil. (Laughter.) I remember that in one of our Colonies an enterprising company sank a bore hole 1500 ft. through solid granite, and they would not have stopped then but for an unsympathetic Colonial Government, which was paying half the cost, calling them to account. How far they would have got by this time I have no idea, but no doubt we should have had a great deal of valuable information. (Laughter.)

There is another point in which a geologist takes particular interest. We have heard a great deal of the extension of the uses of oil. We have heard that oil is used in the air and on land, and we all know that to an ever-increasing amount it is used on the sea. What puzzles the geologist is where all the oil is coming from in future. He may give a lease of fifteen years at the most to the life of free oil if the use is to extend in the way in which it has been doing up to the present, but I do not think any serious geologist would go much further. There are, of course, other directions in which we may look; there is oil shale, and there are substitution products to which allusion has already been made. So far as minerals oil goes, however, I cannot look forward to many further new developments in the future—on land that is to say. I contemplate, however, the time when oil technologists will be compelled to consider if they cannot get a supply from under the sea. Every now and then the Colonial Office receives very interesting reports from different parts of the world to the effect that asphalt, and other products more or less connected with the oil industry, have been thrown up on the sea-shore. There are two theories with regard to that. In the first place, it is held that they are jettisoned from passing vessels, but the second theory is that there is an oil seepage under the sea. If we could only work under a couple of

thousand feet of water we might be able to find an abundant supply of oil. I should be sorry to put any limit whatever on the powers of our oil engineers and even that may come to pass. But whatever may happen in the future I am sure that we—the rest of the world, not actively engaged in the oil industry—can rest assured that our interests will be looked after with the energy, the enterprise and the organisation which has marked the industry in the past. (Applause.)

The proceedings then terminated.

## THE INSTITUTION OF PETROLEUM TECHNOLOGISTS.

THE EIGHTY-FOURTH GENERAL MEETING of the Institution of Petroleum Technologists was held at the Royal Society of Arts, John Street, Adelphi, London, W.C., on Tuesday evening, April 7th, 1925, Sir Thomas Holland, K.C.S.I., K.C.I.E., D.Sc., F.R.S., President, in the chair.

The Secretary read the following list of members elected since the last meeting :—

*Members.*—James Ten-Brœck Bowles, Sir Robert Waley Cohen, Gustav Egloff, David Filitz, William Stenhouse Lamb, Arthur Cumming Michie, Richard Stern, Richard Vernon Wheeler.

*Transferred to Member.*—Arthur Millar, Launcelot Potter Timmins.

*Associate Members.*—James Ellis, George Peters Melville.

*Transferred to Associate Member.*—Alfred John Goodman, Charles Vincent Hill, John Frederick Frank McQueen, Gerald Hugh Scott, Arthur James Vokes.

*Students.*—Richard Harold Coupe, George Leslie Davies.

*Associates.*—Edward Arthur Pearce, William Ernest Shepherd.

The President said he desired to apologise to the reader of the paper, Mr. Stanley Lewis, for bringing him before the Institution just when the holiday spirit had started. He could assure the author that, although the audience was not a large one, it was an appreciatively critical one.

The following paper was then read :—

### Vapour Pressures of Binary and Ternary Fuel Mixtures.

By J. STANLEY LEWIS, B.Sc. (WALES), A.I.C.

The pressure exerted by the vapour of a liquid is one of its most important physical attributes, and the importance that is attached to vapour pressures is revealed by the great amount of elaborate work that has been carried out by many investigators, and these include such names as Reynault, Duhem, Lehfeldt, Ostwald, Roozeboom, and Young. In their work the vapour pressures of pure liquids have been measured, and also of their binary and ternary mixtures, whether partially or completely miscible; the influence of temperature upon vapour pressure has been studied and useful formulæ obtained connecting these variables, as well as various formulæ for calculating vapour pressures of certain mixtures with an accuracy that is in close agreement with the facts.

In recent years attention has been given to the vapour pressures of those liquids or liquid mixtures that are used as fuels in internal-combustion engines, or which may be put to that service in the near future, and though the degree of accuracy of the earlier work has not been attempted in most cases, satisfactory results of a practical nature have been obtained, and it is with this viewpoint that the work has been undertaken generally.

The vapour pressure is an important factor in many ways. Thus the loss incurred on handling or storing these fuels, and the internal pressure developed in shipping containers which are used for transporting them, and also fire risks, are determined to a large extent by the pressure of the vapour at or slightly above ordinary temperatures. Moreover, the ease with which a fuel is vaporised in the carburettor is dependent upon this same factor.

In the present paper the results of vapour pressure determinations on binary and ternary mixtures are recorded, not only with the hope that some of the data may prove useful, but an attempt has been made to reveal certain features of theoretical interest and perhaps practical bearing.

One of the difficulties in determining the vapour pressure of liquids is the presence of dissolved air or gases. In the case of pure liquids, these gases can be removed by prolonged boiling without changing the composition of the liquid; but this is not possible with most liquids of two or more components, the exceptions being the constant boiling point mixtures. The difficulty may be overcome by boiling them under reduced pressure to liberate the dissolved air, which may be removed afterwards as in the apparatus used in the present work.

This instrument (Fig. 1) is a slight modification of that used by Sorel (vide "Carbureting and Combustion in Alcohol Engines") and consists of a barometer tube *A*, the upper part of which contains an enlarged bulb to hold the liquid and vapour. The bulb is surrounded by a water bath which can be brought to the required temperature, and is maintained constant for a sufficient length of time, whilst the bulb is gently rocked or agitated for the liquid and vapour to reach equilibrium before a reading is taken. A capillary tube *B* is attached to the barometer tube at the top and bottom, and both these tubes are in connection with an open manometer *C*. The liquid under investigation is drawn into the bulb, the mercury sealed stopcock closed, and the liquid is boiled under reduced pressure by lowering the manometer *C* to its fullest extent. By raising the manometer the dissolved gases are expelled through the stopcock, which is lubricated with phosphorus oxide, and the process repeated until no further yield of gas is visible. The manometer is then lowered to enable the liquid to produce a small volume of vapour, when the pinchcock at the foot of the barometer

tube *A* is closed. Since the vapour volume is small the change in the composition of the liquid phase is comparatively negligible. A reading of the vapour pressure is obtained by raising the manometer so that the mercury in the tube *B* is brought to a zero mark which corresponds to the zero mark on the vertical mirror scale behind the manometer. The difference between the reading on

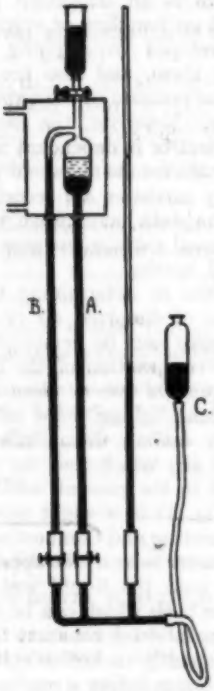



FIG. 1.

the manometer scale and the barometric pressure and corrected to 0°C is the vapour pressure at that particular temperature.

The effect of dissolved air or gases on the vapour pressure is well known, and in some cases is very great. In the case of such complex mixtures as motor spirits, dissolved gases are assuredly present, and their removal may involve considerable error (Tizard and Marshall, Journ. Inst. Petr. Techn., Vol. 8, 31, 1922).

The practical effect of the increase of vapour pressure by dissolved air is obvious in the case of the handling and storage of a spirit, and it has been shown by Dr. Ormandy (Journ. Inst. Petr. Techn., 1923, 9, 33) that the flash points of liquids are considerably lowered.

Moisture is also a factor which raises the vapour pressure considerably of such liquids as hydrocarbons in which it is almost insoluble. The water may be removed by reagents such as calcium chloride, sodium, phosphorus pentoxide, etc., the comparative drying properties of which have been investigated by Sidgwick (J.C.S., 1920, **117**, 1343), and in Table I., results indicate not only the inefficacy of calcium chloride as a drying agent but also the large increase of vapour pressure of hexane and benzene by the small trace of water remaining even after using this reagent. In the drying of hydrocarbons in the following experiments phosphorus pentoxide was employed.

In order to check the accuracy of the apparatus and conversely the purity of the liquids, vapour pressures of specially prepared and purified liquids were determined, and some of these results are shown in Table II.

TABLE I.

*Vapour Pressures of Hexane and Benzene showing the Rise in Vapour Pressures caused by Traces of Water. (a) After shaking up with water and allowing the liquids to separate. (b) Drying by calcium chloride for 24 hours. (c) Drying by phosphorus pentoxide. (d) Young's results for hexane, and Regnault's for benzene. The figures in brackets under Benzene (a) are the sum of the partial vapour pressures of benzene and water.*

Pressures in Millimetres of Mercury.

| Temp. | Hexane. | | | | Benzene. | | | |
|---|---|---|---|---|---|---|---|---|
| °C. | (*a*). | (*b*). | (*c*). | (*d*). | (*a*). | (*b*). | (*c*). | (*d*). |
| 0 | — | — | — | — | 31·5 (31·0) | — | 26·5 | 25·31 |
| 10 | — | — | — | — | 54·8 (55·3) | 48·0 | 46·2 | 45·25 |
| 20 | 135·0 | 123·0 | 119·5 | 120·0 | 93·5 (92·4) | 80·5 | 75·0 | 76·65 |
| 30 | 211·5 | 189·7 | 185·3 | 185·4 | 151·0 (151·3) | 125·6 | 119·5 | 120·24 |
| 40 | 322,5 | 284·5 | 279·1 | 276·7 | 238·9 (239·7) | 192·0 | 184·8 | 183·62 |
| 50 | 478·0 | 411·3 | 403·5 | 400·9 | 364·0 (365·1) | 284·4 | 272·6 | 271·37 |

## BINARY MIXTURES.

When the two components are completely immiscible, the vapour pressure of the mixture will be the sum of their partial vapour pressures. Benzene and, better still, petrol with traces of water, on account of its very small solubility, illustrate this point well, and for practical purposes the vapour pressure of these hydrocarbons, either in the presence of water or saturated with water, may be obtained by the addition of the individual vapour pressures at the specified temperature. This was verified by experiment, and the results for benzene and water have been given in Table I.

TABLE II.

*Vapour Pressures of Pure Liquids in Millimetres of Mercury. The results of Regnault are in brackets.*

| Temp. °C. | Water. | Alcohol. | Benzene. |
|---|---|---|---|
| 0 .. | 4·5 (4·57) | 12·5 (12·70) | 26·5 (25·31) |
| 10 .. | 9·1 (9·14) | 24·0 (24·23) | 46·2 (45·25) |
| 20 .. | 17·4 (17·36) | 44·2 (44·46) | 75·0 (76·65) |
| 30 .. | 31·8 (31·81) | 79·0 (78·52) | 119·5 (120·24) |
| 40 .. | 54·9 (54·86) | 133·5 (133·69) | 184·8 (183·62) |
| 50 .. | 92·5 (91·97) | 220·3 (219·90) | 272·6 (271·37) |

In the case of partially miscible liquids, it may be recalled that the addition of the one component to the other may succeed in raising the vapour pressure of the mixture or in lowering it until finally separation into two phases occurs, but once the two layers are present in contact with the vapour the pressure remains constant for a constant temperature, because the further addition of either component does not alter the concentration of each phase but only the relative amounts. Furthermore, Konowalow established the rule that the vapour pressures of these phases must be equal, as well as the partial pressures of the components in the vapour.

For binary mixtures that are completely miscible Konowalow showed that the vapour pressures of mixtures of different concentrations of two given liquids do not follow the mixture formula as a rule—*i.e.*, the graph indicating the changes of vapour pressure and composition for a given temperature is not necessarily a straight line. Three types of behaviour are possible:—

(*a*) The vapour pressure may lie between those of the components.

(*b*) The vapour pressure may be higher than that of either component. Minimum boiling point mixtures.

(*c*) The vapour pressure may be lower than that of either component. Maximum boiling point mixtures.

As might be expected, the curvature of the graph for two components that are closely related is not very great. Guthrie (Phil. Mag. [v.] 18, 517, 1884) has pointed out that when no heat nor volume change takes place on mixing two liquids, the relation between the vapour pressure and % composition by weight expressed graphically should be a straight line. This, however, does not hold good always. Van der Waals (Proc. K. Akad. Wetensch. Amsterdam, 1900, 3, 170) considered that the relation would be true if the critical pressures of the two substances are nearly equal, and if the molecular weight of each component is normal in the liquid and gaseous state, and the formula of Galitzine and D. Berthelot holds good, namely, $a_{1\,2}=\sqrt{a_1 \times a_2}$ where $a_{1\cdot1}$

represents the attraction of the unlike molecules and $a_1$ and $a_2$ the attraction of like molecules. Then

$$P=\frac{mP_1 + (100-m)\ P_2}{100.}$$

Where $P_1$, $P_2$, and P are the vapour pressures of liquids 1, 2 and mixture respectively, and $m$=molecular percentage of liquid 1.

This has been verified in many cases, for example chlorobenzene and bromobenzene, whose critical pressures are very near. (Young. Trans. C.S. 1902, **81**, 768.) Moreover, it has been found that the difference between the calculated and observed vapour pressures for closely related compounds is very small, even when there is a great difference in critical pressure and also molecular association in the liquid state—*e.g.*, methyl and ethyl alcohols.

These facts may now be applied to the mixing of paraffin hydrocarbons which are present in petrols. Young has shown that in the case of hexane and octane the calculated vapour pressure of 764·6 mm. for equi-molecular proportions was only 4·6 mm. above the observed value. The difference in critical pressure is given as 4·97 atmos. by one authority. For other hydrocarbons which are members of this series the difference in the observed and calculated values may be greater according to the difference in the number of carbon atoms in the molecules. It is reasonable, therefore, to conclude that in blending petrols of high gravity or low vapour pressure with those of low gravity and which consist entirely of paraffins, the resultant vapour pressure of the mixture will not be far removed from that calculated by the mixture-formula.

In order to test this statement in the blending of petrols of a paraffin nature, fractions of Petrol No. 1 (see Appendix) were distilled over, and the vapour pressures of the "cuts" were obtained as well as of their blends (Table III.). It is seen that the vapour

TABLE III.

*Vapour Pressures of Fractions of Petrol (No. 1) and Mixtures of these Fractions. Fraction A=up to 60° C., Fraction B=90–95° C., and Fraction C=115–125° C. The figures in brackets are calculated from the mixture formula.*

| Temp. °C. | 100% A. | 100% B. | 100% C. | 50A/50B. | 50A/50C. | 50B/50C. |
|---|---|---|---|---|---|---|
| 20 .. | 388·6 | 81·7 | 14·8 | 242·5 (235·1) | 219·0 (201·7) | 47·8 (48·3) |
| 30 .. | 560·0 | 127·6 | 26·5 | 354·0 (343·8) | 316·8 (293·3) | 78·8 (77·0) |
| 40 .. | 780·5 | 197·3 | 44·5 | 508·4 (491·1) | 445·7 (414·8) | 123·4 (120·9) |
| 50 .. | — | 292·2 | 69·8 | — | — | 184·9 (181·0) |

pressures of the blends are a little higher than the calculated results, and this difference increases when the fractions are farther apart. Similar results were obtained with "cuts" from Petrol No. 2 (Table IV.).

TABLE IV.

*Vapour Pressures of Fractions of Petrol (No. 2) and Mixtures of these Fractions. Fraction A = 65°–80° C., Fraction B = 80°–95° C., and Fraction C = 95°–110° C. The figures in brackets are the calculated results, based on the mixture formula.*

| Temp. °C. | 100% A. | 100% B. | 100% C. | 50%A/50%B. | 50%A/50%C. | 50%B/50%C |
|---|---|---|---|---|---|---|
| 20 .. | 216·0 | 149·5 | 69·6 | 182·5 (182·7) | 144·2 (141·8) | 109·0 (109·5) |
| 30 .. | 326·4 | 223·0 | 105·5 | 273·8 (274·7) | 221·7 (215·9) | 166·2 (164·2) |
| 40 .. | 456·1 | 321·5 | 157·6 | 389·7 (388·8) | 323·5 (306·8) | 243·3 (239·5) |
| 50 .. | 654·7 | 457·3 | 225·8 | 560·0 (556·0) | 457·0 (440·2) | 342·8 (341·6) |

To find the influence of naphthenes on the vapour pressures of mixtures with paraffins, the vapour pressures of cyclohexane and (*a*) pentane, (*b*) hexane were obtained, as well as vapour pressures of mixtures of petrols of a paraffin nature with those of a naphthene base, from both of which all aromatics had been removed, and in all cases the vapour pressure determined was very close to the calculated figure. For example 50% cyclohexane and 50% hexane were found to have a vapour pressure of 336·6 mm. at 50° C.; the calculated result is 337·8 mm. Again, 50% Petrol 1. and 50% Petrol 3 (see Appendix) have a vapour pressure of 260·0 mm. as against a calculated figure of 261·8.

It may reasonably be concluded that in mixtures of paraffins and naphthenes there is very little association between the two kinds of molecules, and the blending of petrol fractions containing them will give vapour pressures that may be calculated from the mixture formula provided the difference in boiling point is not too great. In most of the examples which have been investigated in this work the observed results have been slightly higher than the calculated, and the difference has been greater the further apart were the fractions taken.

The presence of aromatics undoubtedly raises the vapour pressure above the calculated figure, and this is indicated in Table V., for

TABLE V.

*Vapour Pressures of Mixtures of Benzene with (a) Hexane, (b) Cyclohexane. Figures in brackets are calculated from the mixture formula.*

| Temp. °C. | % Benzene | 100 | 75 | 50 | 25 | 0 |
|---|---|---|---|---|---|---|
| | % Hexane | 0 | 25 | 50 | 75 | 100 |
| (*a*) 20 .. .. | | 75·0 | 95·5 (86·2) | 107·3 (97·2) | 117·8 (108·3) | 119·5 |
| 30 .. .. | | 119·5 | 149·3 (135·9) | 166·7 (152·4) | 182·2 (168·9) | 185·3 |
| 40 .. .. | | 184·8 | 227·0 (208·4) | 251·8 (232·0) | 272·5 (255·5) | 279·1 |
| 50 .. .. | | 272·6 | 335·7 (305·3) | 365·5 (338·0) | 392·8 (370·7) | 403·5 |
| | % Benzene | 100 | 75 | 50 | 25 | 0 |
| | % Cyclohexane | 0 | 25 | 50 | 75 | 100 |
| (*b*) 20 .. .. | | 75·0 | 86·7 (75·7) | 86·9 (76·3) | 85·9 (77·0) | 77·7 |
| 30 .. .. | | 119·5 | 127·8 (120·3) | 130 2 (121·2) | 129·6 (122·1) | 122·9 |
| 40 .. .. | | 184·8 | 196·9 (184·5) | 201·7 (184·1) | 198·7 (183·8) | 183·5 |
| 50 .. .. | | 272·6 | 290·4 (272·5) | 290·1 (272·4) | 291·5 (272·3) | 272·2 |

mixtures of benzene with (*a*) hexane and (*b*) cyclohexane. In the latter case a maximum vapour pressure mixture obtains, and in all probability this holds true for the former. The observed values are very much higher than the calculated in all cases, and in Table VI. it is seen that the presence of benzene in petrols of a

TABLE VI.

*Vapour Pressures of Mixtures of Motor Benzole with (a) Petrol No. 1. (b) Petrol No. 3. The calculated figures are in brackets. In the latter case a maximum vapour pressure mixture obtains.*

| Temp. °C. | % Benzole | 100 | 50 | 0 |
|---|---|---|---|---|
| | % Petrol No. 1 | 0 | 50 | 100 |
| (*a*) 20 | .. .. | 52·7 | 91·0 (87·2) | 121·8 |
| 30 | .. .. | 84·9 | 139·2 (132·8) | 180·7 |
| 40 | .. .. | 131·2 | 207·5 (197·3) | 263·5 |
| 50 | .. .. | 195·4 | 313·2 (277·4) | 359·4 |

| | % Benzole | 100 | 75 | 50 | 25 | 0 |
|---|---|---|---|---|---|---|
| | % Petrol No. 3 | 0 | 25 | 50 | 75 | 100 |
| (*b*) 20 | .. .. | 52·7 | 54·7 (50·6) | 57·0 (48·5) | 53·2 (46·5) | 44·4 |
| 30 | .. .. | 84·9 | 86·6 (81·6) | 89·8 (78·3) | 85·8 (75·0) | 71·7 |
| 40 | .. .. | 131·2 | 135·4 (126·2) | 137·9 (121·1) | 131·0 (116·0) | 111·0 |
| 50 | .. .. | 195·4 | 201·7 (187·5) | 203·5 (179·8) | 194·5 (171·7) | 164·2 |

paraffin and naphthene nature raises the vapour pressure considerably above the figures obtained by the mixture formula, and in the case of motor benzole (see Appendix) and Petrol No. 3, where the vapour pressures of the individual liquids are very close, a maximum vapour pressure of the mixture is possible. This difference in the calculated and observed results is very appreciable even where the vapour pressures of the individual liquids are almost identical.

In view of the increasing practice of blending cracked spirit with light spirits, the vapour pressures of mixtures of untreated cracked spirit (see Appendix) and (*a*) benzene, (*b*) cyclohexane, and (*c*) hexane are given in Table VII. The isothermal curves are

TABLE VII.

*Vapour Pressures of Cracked Spirit with (a) Benzene. (b) Cyclohexane. (c) Hexane. The figures in brackets are calculated.*

| Temp. °C. | % Cracked spirit .. | 100 | 66⅔ | 50 |
|---|---|---|---|---|
| | % Benzene .. .. | 0 | 33⅓ | 50 |
| (*a*) 20 | .. .. .. .. | 91·5 | 88·5 (86·0) | 89·5 (83·2) |
| 30 | .. .. .. .. | 138·2 | 137·7 (132·2) | 137·2 (128·8) |
| 40 | .. .. .. .. | 202·6 | 201·5 (196·6) | 203·3 (193·7) |
| 50 | .. .. .. .. | 288·5 | 290·0 (283·2) | 295·0 (280·5) |

| Temp. ° C. | % Cracked spirit .. % Cyclohexane .. | 66⅔ 33⅓ | 50 50 | 25 75 |
|---|---|---|---|---|
| (*b*) 20 | .. .. .. .. | 85·0 (86·9) | 85·8 (84·8) | 84·8 (81·1) |
| 30 | .. .. .. .. | 131·0 (131·1) | 132·3 (130·5) | 131·6 (126·4) |
| 40 | .. .. .. .. | 195·2 (196·2) | 198·7 (193·1) | 199·0 (188·3) |
| 50 | .. .. .. .. | 281·0 (283·2) | 287·5 (280·3) | 288·8 (276·2) |

| | % Cracked spirit .. % Hexane .. .. | 66⅔ 33⅓ | 50 50 |
|---|---|---|---|
| (*c*) 20 | .. .. .. .. | 95·7 (101·0) | 109·4 (105·8) |
| 30 | .. .. .. .. | 150·5 (154·1) | 165·4 (161·8) |
| 40 | .. .. .. .. | 223·6 (228·0) | 244·2 (240·8) |
| 50 | .. .. .. .. | 320·0 (326·9) | 351·7 (346·0) |

drawn in Fig. 2, and these are of the ~ type. For small concentration of hexane and cyclohexane the calculated values are only very slightly greater than the observed, but the reverse holds good with larger quantities. As before, the values for benzene mixtures are always higher than the calculated for all concentrations.

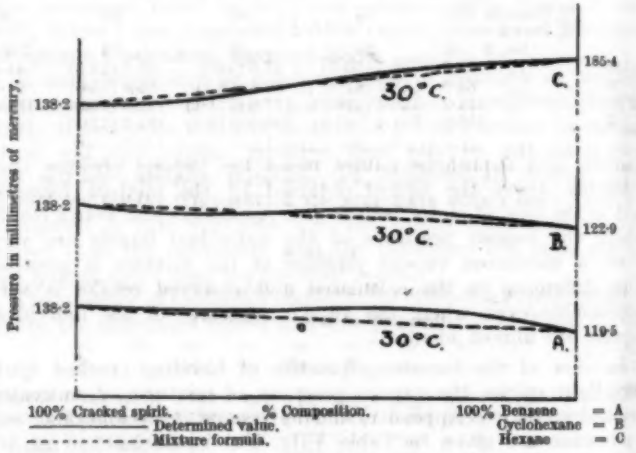



FIG. 2.

The differences are not great, and when equal volumes are taken the resultant vapour pressure is very near the mean of the components. This was verified experimentally with spirits of paraffin and naphthene nature and also for motor benzole, the curves being similar to those in Fig. 2. It was found, also, that 25% of a spirit containing aromatics, when added to 75% cracked spirit, had a vapour pressure almost identical with the calculated.

The isothermal vapour pressure-concentration graph for mixed

liquids not closely related chemically is usually a curve that is convex or concave, and in some cases a point of maximum or minimum vapour pressure obtains. Examples of these are found in mixtures of alcohol with water, benzol or petrol. Mixtures of alcohol and the last two have been investigated by H. Moore and others (J.S.C.I., 1920, 78 T.), and though curves are given there.

TABLE VIII.

*Vapour Pressures of Benzene—Alcohol Mixtures.*

| % Alcohol .. | 100 | 90 | 80 | 70 | 60 | 50 | 40 | 30 | 20 | 10 | 0 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| % Benzene .. | 0 | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 100 |
| Temp, ° C. | | | | | | | | | | | |
| 0 .. | 12·5 | 18·3 | 25·0 | 28·2 | 32·0 | 33·7 | 35·0 | 37·1 | 36·6 | 34 8 | 26·5 |
| 10 .. | 24·0 | 36·5 | 45·5 | 50·1 | 53·5 | 57·1 | 58·3 | 61·8 | 61·0 | 60·2 | 46·2 |
| 20 .. | 44·2 | 63·7 | 76·6 | 84·9 | 89·2 | 93·0 | 97·2 | 98·5 | 98·0 | 97·5 | 75·0 |
| 30 .. | 79·0 | 103·5 | 124·6 | 137·5 | 147·3 | 153·2 | 157·5 | 159·7 | 158·3 | 155·0 | 119·5 |
| 40 .. | 133·5 | 170·6 | 202·4 | 222·0 | 239·3 | 242·9 | 248·0 | 252·5 | 251·2 | 247·3 | 184·8 |
| 50 .. | 220·3 | 284·5 | 320·1 | 344·3 | 362·5 | 373·2 | 382·8 | 386·8 | 385·0 | 377·4 | 272·6 |

TABLE IX.

*Vapour Pressures of Binary Mixtures of Ethyl Alcohol and Petrol No.* 1.

| % Alcohol .. | 100 | 90 | 80 | 70 | 60 | 50 | 40 | 30 | 20 | 10 | 0 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| % Petrol .. | 0 | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 100 |
| Temp, ° C. | | | | | | | | | | | |
| 20 .. | 44·2 | 90·0 | 114·5 | 123·0 | 131·0 | 138·5 | 146·0 | 149·0 | 150·0 | 142·5 | 122·0 |
| 30 .. | 79·0 | 148·5 | 180·0 | 195·0 | 205·5 | 212·5 | 218·0 | 223·5 | 225·0 | 217·0 | 182·5 |
| 40 .. | 133·5 | 231·5 | 279·0 | 298·5 | 315·0 | 324·0 | 332·5 | 336·5 | 338·5 | 322·0 | 250·0 |
| 50 .. | 220·3 | 376·0 | 413·5 | 437·0 | 456·5 | 473·0 | 487·0 | 497·0 | 499·0 | 485·5 | 337·0 |

TABLE X.

*Vapour Pressures of Binary Mixtures of Ethyl Alcohol and Petrol No.* 2.

Pressures in mm. of mercury.

| % Alcohol .. | 100 | 90 | 80 | 70 | 60 | 50 | 40 | 30 | 20 | 10 | 0 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| % Petrol .. | 0 | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 100 |
| Temp, ° C. | | | | | | | | | | | |
| 20 .. | 44·2 | 79·0 | 103·5 | 122·5 | 134·0 | 143·5 | 148·0 | 152·5 | 157·0 | 153·0 | 132·3 |
| 30 .. | 79·0 | 133·5 | 169·0 | 193·5 | 207·0 | 218·5 | 227·5 | 237·0 | 242·5 | 236·5 | 196·0 |
| 40 .. | 133·5 | 217·5 | 263·0 | 293·5 | 318·0 | 338·0 | 351·5 | 358·5 | 367·0 | 360·0 | 282·2 |
| 50 .. | 220·3 | 347·5 | 400·0 | 439·5 | 470·0 | 495·5 | 518·0 | 526·5 | 534·0 | 526·0 | 396·3 |

they are in such a form that approximate comparison only can be made with the present work (Tables VIII., IX., X., and Figs. 3 and 4). The two petrols (No. 1 and 2) used are of different boiling range (see Appendix), and their curves with alcohol vary somewhat. The vapour pressures of alcohol-water mixtures have also been determined by others, but since they were required for some later work (alcohol-water-benzene mixtures), they have been re-determined in the above apparatus and are given in Table XI.

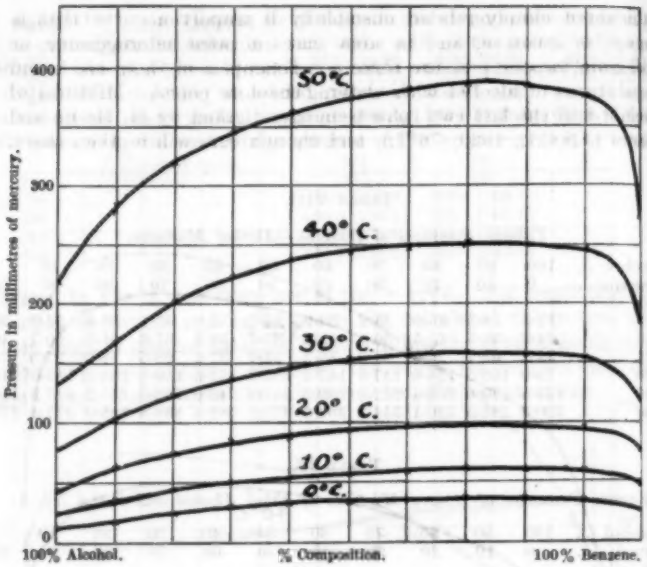



FIG. 3.

TABLE XI.

*Vapour Pressures of Alcohol-Water Mixtures.*

| % Alcohol .. | 100 | 90 | 80 | 70 | 60 | 50 | 40 | 30 | 20 | 10 | 0 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| % Water .. | 0 | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 100 |
| Temp, °C. | | | | | | | | | | | |
| 0 .. | 12·5 | 12·5 | 12·2 | 11·0 | 10·5 | 10·5 | 10·0 | 9·0 | 7·5 | 6·7 | 4·5 |
| 10 .. | 24·0 | 23·3 | 23·0 | 22·4 | 22·0 | 21·2 | 19·1 | 17·6 | 15·8 | 12·5 | 9·1 |
| 20 .. | 44·2 | 42·8 | 41·5 | 38·2 | 37·5 | 36·8 | 34·5 | 31·3 | 26·2 | 22·0 | 17·4 |
| 30 .. | 79·0 | 75·8 | 74·5 | 72·3 | 67·6 | 64·1 | 59·0 | 54·6 | 47·0 | 40·4 | 31·8 |
| 40 .. | 133·5 | 131·0 | 127·9 | 122·5 | 118·5 | 113·0 | 105·6 | 96·5 | 88·4 | 75·1 | 54·9 |
| 50 .. | 220·3 | 217·6 | 215·5 | 208·8 | 198·3 | 189·9 | 180·2 | 167·0 | 148·4 | 125·7 | 92·5 |

## TERNARY MIXTURES.

A possible fuel mixture is that of benzole and alcohol, whose vapour pressures have been given above; but commercial alcohol contains varying amounts of water, hence it is really the ternary mixture of benzene-alcohol-water that requires consideration. This system is only completely miscible within certain limits (Sidgwick and Spurrell. J.C.S., 1920, **117**, 1397, and others), and beyond these limits the mixtures separate into two layers. If, therefore, the composition of the mixture be represented by the triangular method, for a given temperature the heterogeneous condition is marked off by a boundary line, and outside this line

the three components are miscible in all proportions. "Tie lines" may be drawn across this area that indicates heterogeneity, and all concentrations of the three components along a special tie line will separate into two layers having the same concentration, but the relative amount of each phase changes. Along these tie lines the total vapour pressures of the ternary mixtures will be the same for

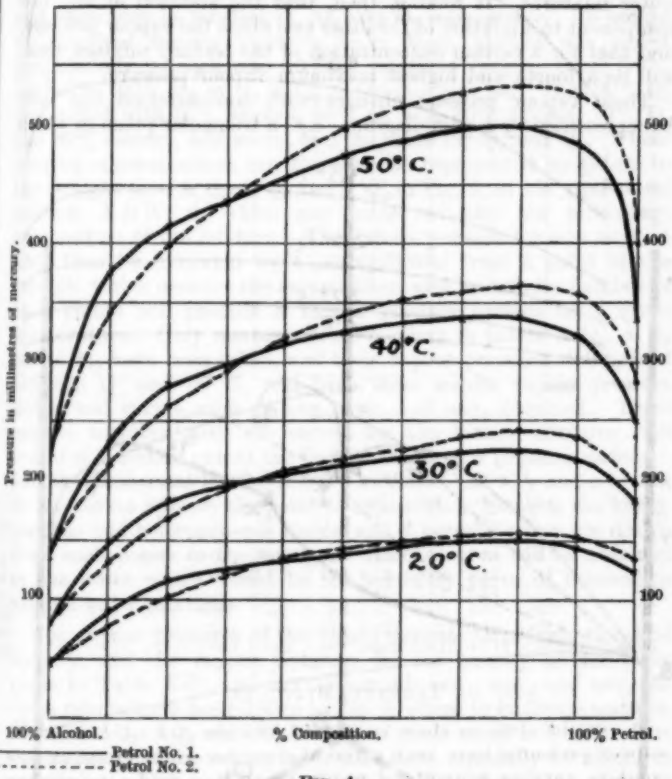



FIG. 4.

constant temperature. Vapour pressure determinations have been carried out for homogeneous and heterogeneous mixtures of this system, between the temperatures of 0° C. and 50° C., and below it will be shown how the limits of solubility may be derived from a study of the vapour pressure curves.

The three liquids benzene, alcohol and water are such that they form three pairs of binary mixtures of the maximum vapour

pressure kind. Thus benzene and water mixtures, on account of the slight solubility of the components, have vapour pressures which are almost the sum of the partial pressures, and as it has been pointed out above the addition of benzene to alcohol and vice versa succeeds in raising the vapour pressure until a maximum point obtains. This phenomenon is also observed in alcohol-water mixtures. It follows, then, that the addition of any one component to a mixture of the other two raises the vapour pressure, and that for a certain concentration of the ternary mixture there will be a fourth and highest maximum vapour pressure.

These vapour pressure changes with concentration can only be represented by a solid diagram—*e.g.*, a triangular prism in which

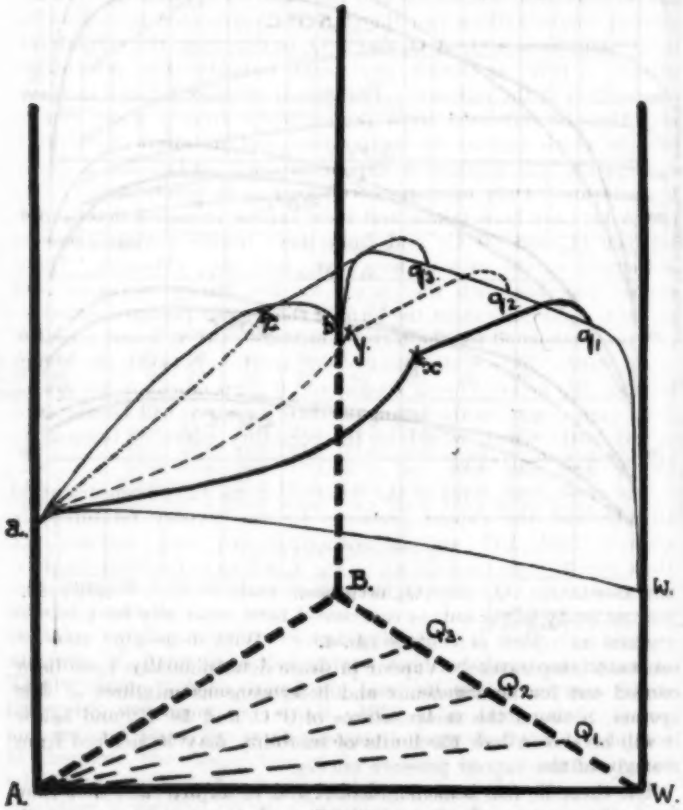



FIG. 5.

any point in the base indicates the percentage composition of the components, and the perpendicular drawn from this point to the vapour pressure surface above represents the vapour pressure of this mixture for that particular temperature. (Fig. 5)

In this part of the work, therefore, mixtures of benzene and water were first prepared consisting of 75%, 50% and 25% of water, and these may be labelled $Q_1$, $Q_2$ and $Q_3$ respectively. To obtain the required ternary mixtures from these, alcohol was added progressively to each one to yield mixtures ranging from 100% alcohol to 100% $Q_1$, or $Q_2$ or $Q_3$, as the case may be. Thus 90% $Q_1$ was mixed with 10% alcohol, 80% $Q_1$ with 20% alcohol, 70% $Q_1$ and 30% alcohol, and so on, and the same for $Q_2$ and $Q_3$. These varying concentrations can therefore be represented by points in the straight lines A $Q_1$, A $Q_2$ and A $Q_3$ in Fig. 5, in the equilateral triangle A B W, in which any point indicates the percentage composition of the mixture. The vapour pressure for any mixture may then be indicated by a perpendicular from a point in the triangle which denotes the composition, and an infinite number of such points will produce a vapour pressure surface for a given temperature. Only mixtures corresponding to points A $Q_1$, A $Q_2$ and A $Q_3$ have been taken, and their vapour pressures determined between 0° and 50° C., and from these results vapour pressure isothermal curves such as $axq_1$, $ayq_2$ and $azq_3$ obtained. These curves, together with the curves for the binary mixtures, will reveal to a certain extent the form of the vapour pressure surface—*i.e.*, the isothermal for the ternary mixture. At x, y and z breaks in the curves appear, the point of demarcation between the homogeneous and heterogeneous stages, and if perpendiculars are drawn from such points to the triangular base, a curve will be obtained in the latter which would be the solubility curve of benzene in alcohol-water mixtures.

The vapour pressures of the binary systems have been discussed already, and the vapour pressures for the ternary mixtures are given in Table XII., and the isothermals $axq_1$, $ayq_2$ and $azq_3$ for these results have been drawn in Fig. 6, where to facilitate matters, the axes $AQ_1$, $AQ_2$ and $AQ_3$ have been made equal in length. The discontinuity of the curves is revealed here, especially for mixtures containing a high percentage of water. With decreasing amounts of water the break becomes less defined until finally a complete continuous curve results, and no heterogeneous phase. These points of demarcation lie along continuous curves denoting the solubility of ethyl alcohol-benzene-water mixtures at varying temperatures.

The system petrol-alcohol-water is very similar to the former, but has not been worked out here in such detail because of the

TABLE XII.

*Vapour Pressures of Ternary Mixtures of Alcohol-Water-Benzene in millimetres of Mercury.*

(a) $Q_1$=75% Water—25% Benzene.

| % Alcohol .. | 100 | 90 | 80 | 70 | 60 | 50 | 40 | 30 | 20 | 10 | 0 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| % Water .. | 0 | 7·5 | 15 | 22·5 | 30 | 37·5 | 45 | 52·5 | 60 | 67·5 | 75 |
| % Benzene .. | 0 | 2·5 | 5 | 7·5 | 10 | 12·5 | 15 | 17·5 | 20 | 22·5 | 25 |
| Temp, ° C. | | | | | | | | | | | |
| 0 .. | 12·5 | 14·0 | 19·5 | 25·0 | 32·5 | 35·0 | 35·0 | 34·0 | 33·5 | 32·0 | 31·5 |
| 10 .. | 24·0 | 28·5 | 36·0 | 46·0 | 57·5 | 63·0 | 63·0 | 62·0 | 61·0 | 59·0 | 54·8 |
| 20 .. | 44·2 | 54·0 | 64·5 | 82·0 | 101·5 | 107·0 | 107·5 | 106·5 | 104·0 | 100·0 | 93·5 |
| 30 .. | 79·0 | 93·5 | 108·0 | 130·5 | 161·5 | 172·5 | 173·0 | 170·5 | 167·0 | 158·5 | 151·0 |
| 40 .. | 133·5 | 152·0 | 176·5 | 207·0 | 251·5 | 277·5 | 279·0 | 275·0 | 268·0 | 257·0 | 238·5 |
| 50 .. | 220·3 | 247·0 | 279·0 | 318·0 | 376·0 | 426·0 | 428·5 | 424·5 | 416·0 | 395·0 | 364·0 |

$Q_2$=50% Water—50% Benzene.

| % Alcohol .. | 100 | 90 | 80 | 70 | 60 | 50 | 40 | 30 | 20 | 10 | 0 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| % Water .. | 0 | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 | 45 | 50 |
| % Benzene .. | 0 | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 | 45 | 50 |
| Temp, ° C. | | | | | | | | | | | |
| 0 .. | 12·5 | 17·0 | 19·0 | 27·5 | 38·0 | 40·0 | 38·5 | 37·0 | 35·5 | 33·5 | 31·5 |
| 10 .. | 24·0 | 32·0 | 40·5 | 50·0 | 61·0 | 65·5 | 62·0 | 61·5 | 59·0 | 57·5 | 54·8 |
| 20 .. | 44·2 | 59·5 | 75·0 | 88·0 | 106·0 | 110·0 | 108·5 | 107·0 | 106·0 | 101·5 | 93·5 |
| 30 .. | 79·0 | 98·5 | 121·5 | 143·0 | 167·5 | 174·5 | 173·0 | 172·0 | 168·5 | 160·0 | 151·0 |
| 40 .. | 133·5 | 162·0 | 194·5 | 230·0 | 262·0 | 278·0 | 278·0 | 276·0 | 273·5 | 258·0 | 238·5 |
| 50 .. | 220·3 | 263·0 | 309·0 | 357·0 | 402·5 | 429·0 | 428·5 | 426·5 | 419·0 | 401·0 | 364·0 |

$Q_3$=25% Water—75% Benzene.

| % Alcohol .. | 100 | 90 | 80 | 70 | 60 | 50 | 40 | 30 | 20 | 10 | 0 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| % Water .. | 0 | 2·5 | 5 | 7·5 | 10 | 12·5 | 15 | 17·5 | 20 | 22·5 | 25 |
| % Benzene .. | 0 | 7·5 | 15 | 22·5 | 30 | 37·5 | 45 | 52·5 | 60 | 67·5 | 75 |
| Temp, ° C. | | | | | | | | | | | |
| 0 .. | 12·5 | 17·0 | 22·0 | 26·5 | 30·5 | 34·0 | 35·0 | 36·5 | 36·0 | 34·0 | 31·5 |
| 10 .. | 24·0 | 34·0 | 44·5 | 50·0 | 57·0 | 61·5 | 62·5 | 64·5 | 64·0 | 60·0 | 54·8 |
| 20 .. | 44·2 | 61·5 | 80·0 | 91·0 | 101·0 | 107·5 | 108·0 | 109·0 | 110·0 | 103·5 | 93·5 |
| 30 .. | 79·0 | 104·0 | 129·5 | 148·5 | 163·5 | 172·5 | 174·5 | 176·0 | 175·0 | 168·0 | 151·0 |
| 40 .. | 133·5 | 172·5 | 210·0 | 235·0 | 261·0 | 276·0 | 278·0 | 277·5 | 279·5 | 269·0 | 238·5 |
| 50 .. | 220·3 | 277·0 | 323·5 | 364·5 | 397·5 | 419·0 | 428·5 | 430·0 | 430·0 | 414·5 | 364·0 |

small solubility of water in petrol-alcohol mixtures and the triangular solubility diagram is almost entirely occupied by the heterogeneous phases. Vapour pressures were obtained for mixtures of petrol (No. 1) with (*a*) 98's alcohol and (*b*) 95's alcohol for concentrations varying from 100% of petrol to 100% of the alcohols of above strengths, (*c*) and also for 90's alcohol. A maximum ternary vapour pressure mixture can be obtained also from these three components, and this is foreshadowed in the results for Petrol (No. 1) with the above alcohol strengths (Table XIII.). From the curves

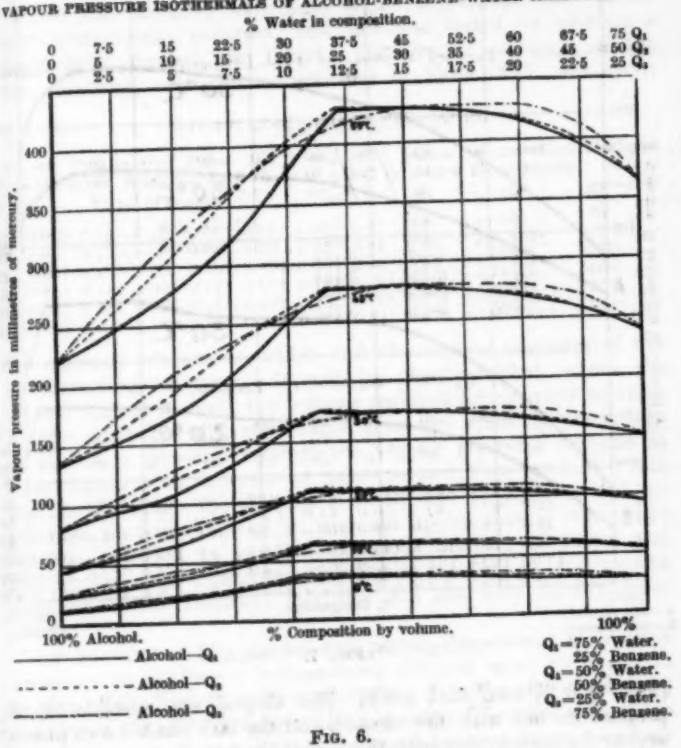



FIG. 6.

TABLE XIII.

*Vapour Pressures of Petrol No. 1 mixed with (a) 98's Alcohol, (b) 95's Alcohol. The figures in brackets are approximate from curves.*

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| % Petrol No. 1. .. | 100 | 90 | 80 | 60 | 40 | 60 | 100 | |
| % 98's Alcohol .. .. | 0 | 10 | 20 | 40 | 60 | 100 | | |
| Temp, ° C. | | | | | | | | |
| (a) 20 .. .. .. | 121·8 | 160·5 | 158·0 | 153·0 | 135·5 | (44·5) | | |
| 30 .. .. .. | 180·7 | 247·0 | 247·5 | 234·5 | 211·5 | (79·0) | | |
| 40 .. .. .. | 263·5 | 373·0 | 371·5 | 358·0 | 323·0 | (133·5) | | |
| 50 .. .. .. | 359·4 | 552·5 | 548·0 | 523·0 | 485·0 | (220·5) | | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| % Petrol No. 1. .. | 100 | 95 | 90 | 80 | 70 | 50 | 30 | 0 |
| % 95's Alcohol .. .. | 0 | 5 | 10 | 20 | 30 | 50 | 70 | 100 |
| Temp, ° C. | | | | | | | | |
| (b) 20 .. .. .. | 121·8 | 161·0 | 161·5 | 160·5 | 153·5 | 147·0 | 134·0 | (44·0) |
| 30 .. .. .. | 180·7 | 249·5 | 250·0 | 250·0 | 239·0 | 230·5 | 211·0 | (78·5) |
| 40 .. .. .. | 263·5 | 376·5 | 380·0 | 380·0 | 365·5 | 349·0 | 321·5 | (133·0) |
| 50 .. .. .. | 359·4 | 551·5 | 564·5 | 559·0 | 540·0 | 522·0 | 477·0 | (220·0) |

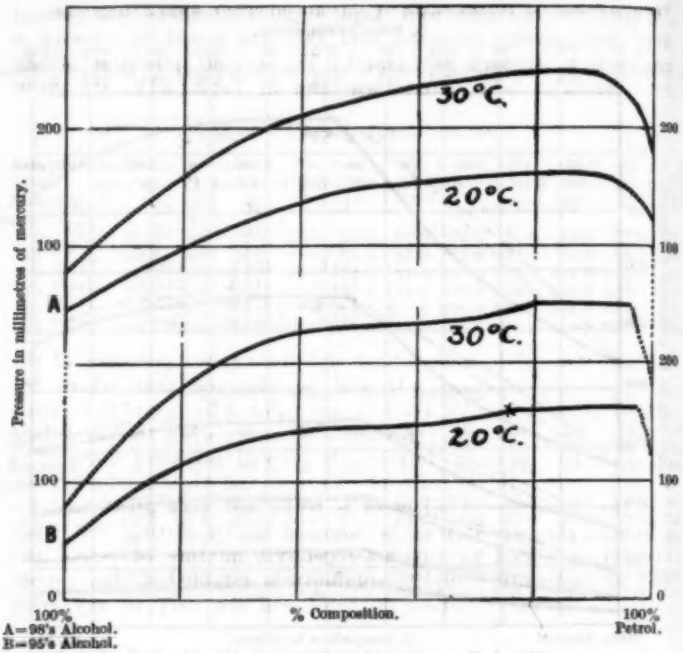



FIG. 7.

(Fig. 7) it is seen that petrol—98's alcohol are miscible in all proportions but with 95's alcohol, and the 90's alcohol two phases appear for certain concentrations, also the vapour pressures of the petrol-alcohol-water mixtures during the heterogeneous conditions are almost equal throughout at similar temperatures. This is due probably to the fact that the line representing the changes of concentration practically coincides with the tie line for conjugate solutions.

The addition of benzene to these conjugate solutions in sufficient quantity results in a homogeneous mixture, and so it was decided to find out the quantity of benzene necessary in each case to produce complete miscibility, and to determine the vapour pressure of the resultant mixture. Four mixtures of petrol and 95's alcohol were made containing (*a*) 95%, (*b*) 90%, (*c*) 85%, (*d*) 80% of petrol, and at 20° C. these separate into two liquid phases, and, as pointed out above, the vapour pressures for all these mixtures vary very slightly indeed.

Whilst the mixtures were kept at 20° C. benzene was added until homogeneity occurred, and this was tested by viewing a bright light through the liquid. The vapour pressures of the final mixtures were determined, and in Table XIV. are given

TABLE XIV.

*Vapour Pressures of Petrol No. 1 and 95's Alcohol in quantities that give Heterogeneous Mixtures, and Benzene added to restore Homogeneity.*

| | Vols. of Petrol .. | 95 | 90 | 85 | 80 |
|---|---|---|---|---|---|
| Temp. | „ 95's Alcohol .. | 5 | 10 | 15 | 20 |
| °C. | „ Benzene .. | 56 | 11 | 4·5 | 1·8 |
| 20 | .. .. .. .. | 151·0 | 156·5 | 158·0 | 157·0 |
| 30 | .. .. .. .. | 234·5 | 246·5 | 244·5 | 244·0 |
| 40 | .. .. .. .. | 355·5 | 373·0 | 372·0 | 372·0 |
| 50 | .. .. .. .. | 521·0 | 553·0 | 550·0 | 548·0 |

the amounts of benzene added and the vapour pressures of the corresponding mixtures. It will be observed that where the alcohol content is small, the benzene required for complete solution is large, compared with the volume necessary when the percentage of alcohol is greater; further, the vapour pressures increase to a maximum with decrease of benzene and then gradually fall, but the difference in all cases is really not very great, and for practical purposes it may be summed up by stating that when benzene is added to any heterogeneous mixture of petrol and 95's alcohol until complete solubility is established, the vapour pressures of the resultant mixtures will not vary to any great extent.

For mixtures of 90's alcohol and petrol, the amount of benzene necessary to produce a homogeneous solution must be larger on account of the higher percentage of water. In the case of mixtures with more than 50% of petrol the amount of benzene required is excessive, more than a 1000 volumes of benzene being necessary for dissolving 60 volumes of petrol and 40 volumes of alcohol. The only case considered here is 50% petrol and 50% of 90's alcohol, and the volume of benzene and the vapour pressures of the homogeneous product are given in Table XV.

TABLE XV.

*Vapour Pressures of Heterogeneous Mixture of (a) 90's Alcohol and Petrol (No. 1) and (b) Benzene added to former mixture at 20° C. until Homogeneous Solution obtained.*

| Temp. °C. | (a). Petrol 50 vols. Alcohol 50 vols. | (b). Petrol 50 vols. Alcohol 50 vols. Benzene 42 vols. |
|---|---|---|
| 20 .. .. .. .. | 153·8 | 142·0 |
| 30 .. .. .. .. | 238·0 | 222·7 |
| 40 .. .. .. .. | 354·9 | 343·4 |
| 50 .. .. .. .. | 550·0 | 531·9 |

Finally, in Table XVI. the vapour pressure results for ternary mixtures of crystallisable benzene, ether and 98's alcohol are recorded.

TABLE XVI.

*Vapour Pressures of Mixtures of Benzene (crystallisable), Ether and 98's Alcohol.*

| % Benzene .. | 25 | 50 | 75 | 25 | 50 | 75 | 25 | 50 | 75 | 25 | 50 | 75 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| % Ether .. | 75 | 50 | 25 | 37·5 | 25 | 12·5 | 56·25 | 37·5 | 18·75 | 18·75 | 12·5 | 6·25 |
| % Alcohol .. | 0 | 0 | 0 | 37·5 | 25 | 12·5 | 18·75 | 12·5 | 6·25 | 56·25 | 37·5 | 18·75 |
| Temp., °C. | | | | | | | | | | | | |
| 20 .. .. | 350 | 247 | 157 | 224 | 182 | 138 | 283 | 210 | 155 | 146 | 138 | 122 |
| 30 .. .. | 514 | 365 | 235 | 339 | 273 | 219 | 419 | 320 | 240 | 230 | 216 | 194 |
| 40 .. .. | 720 | 528 | 342 | 502 | 412 | 336 | 616 | 478 | 365 | 351 | 331 | 302 |
| 50 .. .. | — | 721 | 505 | 737 | 610 | 505 | — | 728 | 538 | 540 | 508 | 460 |

APPENDIX.

| | Petrol 1 (Paraffin). | Petrol 2 (Paraffin). | Petrol 3 (Naphthene). | Motor Benzole (Aromatics). | Cracked Spirit (Unsaturated). |
|---|---|---|---|---|---|
| Specific gravity .. | 0·705 | 0·735 | 0·756 | 0·875 | 0·789 |
| Initial boiling point .. | 35° C. | 40° C. | 65° C. | 70° C. | 43° C. |
| % Distilled over at | | | | | |
| 50° C. .. .. | — | — | — | — | — |
| 75 .. .. | 21 | 9 | — | — | 7 |
| 100 .. .. | 65 | 43 | 26 | 59 | 42 |
| 125 .. .. | 91 | 76 | 90 | 89 | 76 |
| 150 .. .. | — | 92 | — | — | 89 |
| 175 .. .. | — | 97 | — | — | 95 |
| Final boiling point .. | 140° C. | 175° C. | 139° C. | 144° C. | 179° C. |
| Total distillate .. | 96·5 | 98·0 | 97·0 | 98·0 | 97·5 |
| Residue in flask .. | 2·0 | 1·7 | 2·0 | 1·0 | 1·5 |
| Loss .. .. .. | 1·5 | 0·3 | 1·0 | 1·0 | 1·0 |

Petrols 1, 2, and 3 were treated with Sulphuric Acid, washed and dried.

In conclusion, the author wishes to acknowledge his indebtedness to Prof. J. S. S. Brame, who has provided the apparatus, etc., for carrying out the experiments and at whose suggestion the work was undertaken. Moreover, the author wishes to take this opportunity to thank him for his valuable suggestions and for his kindly supervision throughout.

## *DISCUSSION.*

**The President** said he was sure it was the wish of the members that he should convey the thanks of the Institution to the author for his very interesting paper, which obviously was the result of a clean and straightforward piece of research work very clearly expressed. So far as he could judge the paper had one fault, namely, that the results given were so conclusive that they admitted of very little discussion, or at any rate of less discussion than was customary in regard to the papers read before the Institution. The author had dealt with products that were pure, and he had no

doubt that some of the members would make this comment on the paper, not by way of criticism, that the author was dealing with ideal materials which they were not accustomed to handle very often; but the pure chemist was as necessary to the petroleum technologist as the mathematician was to the engineer. He thought the members would be justified if he, as a geologist, attempted to criticise a paper on pure chemistry, in coming to the conclusion that he could not at any rate be a good geologist, and he would not, therefore, run the risk of attempting to trespass on his neighbours' garden; but in the Institution of Petroleum Technologists, which was a ternary mixture of geologists, chemists and engineers, he would like to see how the vapour pressure index of discussion would rise after the reading of the author's paper. He felt, however, as he had previously stated, that the paper was too obviously straightforward in recording simple results to admit of discussion of anything but the general subject.

**Prof. J. S. S. Brame** said the time had to be looked to, if it had not already arrived, when a simple petroleum distillate would not be used as a fuel for internal combustion engines, but when mixtures of fuels of different characters would be used, primarily petrol, aromatic hydrocarbons and alcohol mixtures. Therefore it was a matter of very great importance to ascertain in what form of combination the best results could be obtained from the point of view of permanent homogeneity at different temperatures (a subject on which Dr. Ormandy and others had worked) and also from the point of view of fuel mixtures, which had a maximum vapour pressure. There were some interesting points in connection with the question of blending petrols from different sources. It was well known to members of the Institution that a casing-head spirit was frequently blended with heavier types of naphtha, and the effect of using a distillate of very low boiling range, like a natural gas spirit with a distillate of higher boiling range, was a matter of some considerable importance from an industrial point of view. Those points had to a certain extent been met in Tables III. and IV., where the author had taken "cuts" of different boiling range and the effect of blending had been ascertained. In those cases the author had found that the greater the difference in the boiling range the greater the difference between the calculated vapour pressure and the observed vapour pressure. But as showing that more information was required, there was a contradiction in the results between the petrols shown in Table III., petrol No. 1 and Table IV., petrol No. 2, because the result, 50 per cent. of fraction A. and 50 per cent. of fraction B., in the case of petrol No. 1, showed that the differences were 7·4, 10·2, and 17·3 millimetres above the calculated pressure. Taking Table IV., it

would be seen that the blending of 50A with 50B gave results which were practically identical with the calculated results. It was seen, therefore, that some qualification was necessary in the statement made on Page 3: "It is reasonable, therefore, to conclude that in blending petrols of high gravity or low vapour pressure with those of low gravity and which consist entirely of paraffins, the resultant vapour pressure of the mixture will not be far removed from that calculated by the mixture-formula." There were some other interesting points which had cropped up during the course of the experiments. One which astonished him was the effect which small quantities of water, quantities quite soluble in the different liquids, had on the vapour pressure. It would be seen from the action of different drying agents how necessary it was to get the material perfectly dry, and he did not think that was a point to which attention had been specifically directed in that connection before. The question of the removal of dissolved air and dissolved gases was, perhaps, the most debatable point in the whole paper, particularly in how far one was justified in removing the air or dissolved gas, whichever it might be. The question of dissolved gas, *i.e.*, hydrocarbon gas, became of importance with cracked spirit or casing-head spirit in both of which the quantity of dissolved gas might be considerable, and the removal of these gases, which added very materially to the vapour pressure of the liquid was wrong. Petrol was not a very homogeneous substance, and he felt the work done by the author could very profitably be extended on the lines of the present paper to deal with more specifically pure products than the author had dealt with hitherto. The author had dealt with hexane and heptane as paraffins, and with cycloparaffins like cyclohexane, and with benzene, representing the aromatics, and with cracked spirit, with regard to which he could not say what it represented, and he did not think anybody else could. But he did feel there was scope for very much further investigation in regard to the effect on vapour pressure of mixing pure hydrocarbons of different types one with the other. He was quite sure the author would like to carry on the work still further. The only point in that connexion was the availability of material for the experiments. Some of the members of the Institution might, perhaps, be able to help by supplying small quantities of fairly pure specimens of typical hydrocarbons, which could be used in carrying out further investigations, which he was sure would add very considerably to the knowledge we at present possessed.

**Mr. Arnold Philip** congratulated the author on the very interesting manner in which he had brought the subject forward, accompanied as it was by most carefully prepared diagrams. The slides showing the curves were excellent. Speaking only from

the standpoint of one interested in technical laboratory testing, it appeared to him that the paper was rather more theoretical than practical. He, of course, knew that the results given in the paper were all obtained from practical experiments but, as Professor Brame had said, volatile fuels as met with in practice actually contained dissolved gases, and he would further add that water was also always present. The results obtained by the author, therefore, could not have a direct application to the estimation of the pressures occurring in petrol tins during transit.

Personally, he was inclined to favour the direct operation of obtaining the vapour pressures in samples of mixed volatile liquids as received by the U-tube boiling point method.

**Mr. E. Lawson Lomax** said he was rather at a loss what to say in regard to the paper because it contained such a mass of information that it required some time to digest it, but there were a few points to which he would like to draw attention. Prof. Brame had referred to the question of dissolved gases. Personally, he was rather doubtful whether in the case under discussion it was wise to take out the dissolved gases. Undoubtedly in the case of cracked spirit, and particularly in the case of casing-head spirit, with the present methods of absorption, dissolved gases were taken up which played quite a considerable part in the easy starting of the fuel. Taking those things into consideration, he did not think the dissolved gases, *i.e.*, the hydrocarbon gases, should be removed. He did not suppose the air could be removed without removing the hydrocarbon gases; he thought the one had to be taken out with the other. With regard to the question of water, which was quite an important one, it had been said by many people that the addition of a little water to petrol improved the running of the engine. Personally, he wondered what percentage of water could be dissolved in petrol, what the effect of each small additional percentage of water was, and whether the vapour pressure was raised proportional to the amount of water present. In the mixture of aromatic hydrocarbons with naphthenes and paraffins a maximum vapour pressure was obtained, but it was well known that in such a mixture there was a change in volume, accompanied by a change in specific gravity. There seemed to be an association of some kind, and he had been wondering whether there was any relation between the increase in vapour pressure and the molecular association or decrease in volume or increase in specific gravity above the calculated specific gravity. He did not know whether the author had met with that in the results he had obtained; if the author made further experiments, perhaps, he would be able to get some relation between them. That might have an effect on the mixtures in tablet IX. and X. and in tables

III. and IV., where there was in the case of one petrol a tremendous increase in the vapour pressure above the calculated one of the 50-50 mixture, while in the other nothing of the kind occurred. The presence of the aromatic hydrocarbons, if there were any, in those spirits might account for some of those things. With regard to ternary mixtures, if ternary mixtures of the kind described in the paper were going to be used, and a maximum vapour pressure was obtained from a stable ternary mixture, it would affect enormously the distillation tests. It would be necessary to get out new distillation tests for those ternary mixtures, and probably the work that the author had been doing would give some guide as to what the distillation limits ought to be with those ternary mixtures.

**Mr. E. R. Redgrove** congratulated the author upon a scientific paper which, as Prof. Brame had said, was bound sooner or later to find practical application, because with the great increase in the demand for internal combustion engine fuel, it would certainly be necessary to turn to sources other than petrol as it was now known. Speaking as a scientist, he appreciated greatly the work the author had done. As a chemist whose business it was to provide lubricants for internal combustion engines, he saw another danger ahead of the industry. At present the mortality amongst big ends was quite large enough, but if the author continued his investigation and found that the addition of 1 or 2 per cent. of some known or at present unknown chemical to, say, kerosene would give a satisfactory fuel, an enormous amount of high boiling point long end would be present in the fuel, which undoubtedly would find its way very largely into the crank case, and then the lubricating oil manufacturers would receive far more blame than was at present the case, and that was saying a lot. He loved scientific research, but he was bound to say that he viewed the future with a certain amount of disquiet.

**Mr. Gordon Pitt** said he did not think that, either as an Institution or as an industry, it was desirable to listen too sympathetically to the complaints of a lubricating oil manufacturer when a fresh field in regard to fuel was opened in front of them, although he appreciated their difficulties, particularly in regard to big end mortality. He disagreed with the suggestion that had been made that for work of the kind done by the author more strictly practical considerations should govern the lines on which it was carried out. It was distinctly unusual in this country in particular, for accurate scientific work to be done in advance of practical requirements. There was no doubt that practical requirements in the way of a wider range of fuels was looming largely on the horizon, and it seemed to him it could only be of advantage

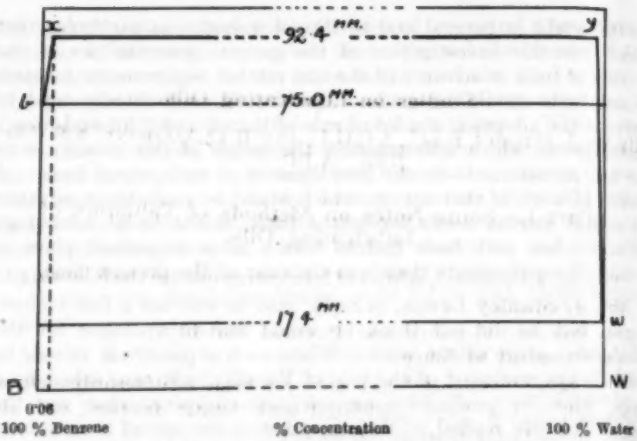
to the world in general and to the oil industry in particular that strict scientific investigation of the general potentialities of the mixing of fuels in advance of the real market requirements for such mixed fuels should be made. That would undoubtedly tend to prevent the adoption of a lot of rule-of-thumb and "hit-and-miss" methods—to which unfortunately the people of this country were far too accustomed—in the development of such mixed fuels. A record of work of that nature. which would be available in advance of actual market needs for mixed fuels, would be of advantage as and when such fuels had to take a more important place in practical requirements than was the case at the present time.

**Mr. J. Stanley Lewis,** in reply, said he was not a fuel technologist, but he did not think he would like to apologise for the academic nature of the work. When such a point was raised, he was always reminded of the tale of Faraday, who was asked by a lady, when he produced some scientific curiosity, what was the use of it. He replied, "Madam, what is the use of a new born baby"? Perhaps in time he hoped some of the work he had done might be of use to the members who were fuel technologists. A point had been raised in regard to dissolved air or dissolved gases. He realised at the beginning of his experiments that that point might crop up, and he had mentioned in his paper the names of Tizard and Marshall, who had published a paper* in which they stated they had taken account of the dissolved air and gases in their work. In his own experiments he had used mostly pure liquids, such as water, alcohol, hexane, and benzene, and in that case it was only the dissolved air which could be boiled off. The quantity of vapour which could be removed would be very inappreciable compared with the total volume of the liquid. He realised, however, that in the case of mixtures, such as petrols, the gases present, if they were removed during the vapour pressure determinations, a considerable error might occur. Another question had been raised in regard to the addition of water to petrol and benzole. One or two experimenters had, he believed, determined the solubility of water in petrol mixtures, but he could not recall their names at the present moment. This effect of small traces of water could best be shown in the case of benzene.

If Ww represented the vapour pressure of water and Bb the vapour pressure of benzene, the curve should be something like bxyw for benzene and water. Starting with 100 per cent. of benzene the addition of very minute quantities of water would raise the vapour pressure as in bx. That would be the vapour pressure of the water in benzene. The limits were very small and at x heterogeneity commenced.

At 20° C. this point was reached after the mixture contained about 0·06 per cent. of water, after which the benzene-water

* Journ. Inst. Petr., 8, 31, p. 217. April, 1922.




mixture consisted of two phases with constant vapour pressure corresponding to the horizontal line xy, which was the sum of the partial vapour pressures of water and of benzene. Therefore the maximum vapour pressure, and which was equal to the sum of the vapour pressure of the components, was obtained by the addition of only 0·06 per cent. of water to benzene. In the case of petrols the quantity of water necessary to give the maximum vapour pressure, *i.e.*, a vapour pressure equal to the addition of the vapour pressure of petrol and of water would be smaller on account of the lesser solubility of water in petrol. He believed this would be of the order of 0·02–0·03 per cent. of water. Thus it would appear from the tables above that dry benzene has a vapour pressure of 75·0 mm., but the addition of only 0·06 per cent. of water raised this to a vapour pressure of 92·4 mm. at 20° C. If the graph bx was a straight line then this would give the vapour pressure for benzene containing varying amounts of water from 0 to ·06 per cent. He had nothing to say to Mr. Lawson Lomax in regard to the question of the distillation tests of motor fuels containing constant boiling point mixtures, but thanked him for his suggestion of correlating vapour pressures of mixtures with changes in volume, heat and specific gravity. Very little work had been done on this subject. He had very small knowledge of lubricants, and he would not attempt to reply to Mr. Redgrove's remarks on that subject.

**The President,** in conclusion, proposed the thanks of the Institution to the author for his very interesting paper.

The resolution of thanks was carried by acclamation, and the meeting terminated.

# Studies on Lubricating Oils.

By W. J. Wilson, F.I.C., A.C.G.I., and B. C. Allibone, A.R.C.Sc., B.Sc., A.I.C.

## Part I.—Some Notes on Methods of Valuation of Lubricating Oils.

The chief desirable qualities of lubricating oils are the following :—

(1) "Oiliness,"

(2) Suitable Viscosity and Physical Stability.

(3) Chemical Stability.

The term "Oiliness" has not yet been satisfactorily defined, although it has been associated with [1]static friction and also with [2]inter-facial tension (oil-water).

There would seem to be little reason to question the value of a determination of the static friction of an oil film between two suitable metal surfaces, especially as so admirable an instrument as that of Deeley has been devised for the purpose. The difficulty and cost in time of preparing metal surfaces of the character required for such a test, and also the necessity for meticulous care in protecting the prepared surfaces from dust, etc., render the latter unsuitable for routine purposes, but any simpler modification of this apparatus and test, or any other form of test giving definitely parallel results and of suitable character, would surely give results of much value.

Physical Stability includes among other properties a low rate of fall of viscosity with rising temperature, a low volatility, and a sufficiently low solidification temperature. These properties are adequately and directly indicated by the customary methods of physical testing.

Chemical Stability is the most variable property of oils from different sources, and the property the evaluation of which is most difficult. It comprises in the main (1) resistance towards oxidation, and (2) resistance towards decomposition under high temperature conditions. In view of the importance of these properties, it is surprising that only intermittent attempts have been made to establish scientific methods of assessing them.

Some proposed methods have never been adopted, their results being uncertain and also devoid of practical significance. Two

[1] Deeley, *Proc. Phys. Soc.*, **32** (2).

[2] Wells and Southcombe, *J. Soc. Chem. Ind.*, **39**, 51T ; *cf.* Hyde, *Engineering*, 111, 708 ; *J. Soc. Chem. Ind.*, **40**, 500A.

forms of tests for Chemical Stability have become standardised, *viz.*, the Conradson Coking Test and the Oxidation, or Sludging, Test.

The Conradson Coking Test is found to be reliable, provided that similar apparatus is always employed. It is necessary to point out, however, that the existing specification does not ensure that condition. Thus the description of the outer crucible admits of a large variation of the thickness of the metal. In consequence of this the authors' laboratory was supplied by an American firm with a crucible weighing 80 grams (without cover), and by a London firm with one weighing 570 grams. Silica and porcelain inner crucibles are found to give different results, the latter being preferred, while the unnecessary indefiniteness of the dimensions of the hood is believed to constitute a further possible cause of variation. The authors find that, the external crucible being reasonably light and thin and given uniform apparatus, the test can be conducted quite easily in $30\pm1$ minutes, and under these conditions results can readily be duplicated with accuracy. They are of opinion, however, that all the dimensions of the several parts of the apparatus should be exactly specified, with only small tolerances, an improvement which should involve little, if any, addition to the cost of the apparatus.

The value and significance of this test remains uncertain, and one would hardly venture to go beyond a statement that in the selection of an oil, other things being equal, the oil having the lowest Coking Value would be preferred.

The test is applicable only to comparatively heavy lubricating oils, as in the case of lighter oils the Coking Values are too low to admit of differentiation.

The standard Oxidation Test is open to many objections.

(1) The conditions of the test, particularly its duration and the temperature to which the oil is heated require to be determined by data indicating the optimum differentiation between oils. Thus the comparative changes occurring in two oils in 40 hours may be in altogether different proportions from the changes of the same oils in 20 hours under the same conditions. It is necessary therefore to determine what time and conditions most truly indicate the relative values of the oils.

(2) The test measures the quantity of "sludge" formed, but other products of oxidation, such as acids, are ignored. Further the "sludge" itself is of highly variable character, so that a merely numerical value may be entirely misleading.

(3) Results obtained by different operators with duplicate samples are frequently in serious disagreement.

(4) The time occupied by the first part of the test (45 hours) is inconveniently long for most laboratories. For a test to be of general value it must be possible to complete any stage of it within an ordinary working day, unless it can be left overnight without attention and without risk.

To satisfy these objections would require an extensive programme of experiments, which could best be undertaken by the collaboration of several laboratories. For their own use, as some form of this test is essential even though the results must be regarded with reserve, the authors have modified the apparatus and conditions of the test. A reduction of the time of oxidation from 45 to 6 hours, and omission of the use of copper foil have been partly compensated by raising the temperature from 150° to 170° and by using oxygen instead of air. With occasional variations results are generally in a constant ratio to those obtained by the standard test. As the conditions tentatively adopted remain quite arbitrary and most of the objections above referred to still obtain, it is unnecessary to specify the details of apparatus and procedure.

Disagreement of results obtained in different laboratories is probably largely due to a want of appreciation of the magnitude of some of the possible sources of error. Two of these, *viz.*, irregularities of temperature and the quantity of air passed through the oil are not likely to be overlooked, but their accurate control is not easily contrived. A third is the presence of traces of foreign substances. Waters quotes an instance in which an oxidation value was increased from 0·55 to 0·91 apparently owing to the presence of dust (U.S. Bur. of Standards Circ. 99). He gives other instances of the catalytic effect of various substances (J. Ind. Eng. Chem. 13, 901).

The authors find that small quantities of solid substances, including metal powder and ordinary dust, may increase the formation of asphaltic substances to a remarkable degree.

Oil "A."

| | Asphalt. % |
|---|---|
| Free from solid matter | 0·91 |
| With 0·1 per cent. copper powder | 3·01 |
| 0·1 per cent. ordinary dust | 4·13 |
| 0·1 per cent. steel powder | 4·06 |
| 0·1 per cent. carbonaceous matter from motor cylinder | 3·50 |
| 0·1 per cent. bearing metal powder | 1·88 |

Oil "B."

| | |
|---|---|
| Free from solid matter | 0·52 |
| With 0·1 per cent. copper powder | 1·29 |
| 0·1 per cent. ordinary dust | 0·56 |
| 0·1 per cent. carbonaceous matter from motor cylinder | 0·66 |
| 0·1 per cent. bearing metal powder | 0·87 |

Although this action may possibly not be significant in a test in which copper foil plays a similar part, the results at least indicate the advisability of ensuring that the samples for testing be free from traces of dust or other foreign substance, and that the oxygen or air be adequately purified.

A further source of variation of results is want of exact uniformity of the measurements of the flask or other vessel containing the oil, and the size and position of the inlet tube for the air or oxygen, i.e., the dimensions which determine the depth of oil through which oxygen passes, and the size of the gas bubble. These factors are believed to be of great importance.

## Part II.—An Investigation of the Composition of the Lubricating Oil Constituents of Petroleum Before and After Distillation.

In the present work no attempt has been made to isolate individual hydrocarbons. It was believed that a separation, or at least a partial separation, of two or three homologous series of hydrocarbons could be achieved, that some indication of the degree of change occurring during distillation and, to a less extent, during refining, could be discovered, and that a study of the separated groups might shed some light upon the relations of the varying physical and chemical properties of lubricating oils with their compositions.

The method finally selected for the separation required was that of fractional solution in a solution of sulphur dioxide in acetone. Liquid sulphur dioxide is not easily handled or measured, and at the low temperatures at which it is necessary to employ it oils containing small quantities of paraffin become solid. The sulphur dioxide-acetone solution was found to be equally valuable as a selective solvent, and could be used at room temperature. A solution containing 40 per cent. by weight of sulphur dioxide was employed throughout this work.

The oils chosen for experiment were a crude oil from a source in Burmah and a distillate fraction from the same crude oil. This fraction was a middle cut from the redistillation with steam and vacuum of the blue oil, i.e. lubricating oil distillate from which paraffin had been removed by filtration. The latter was distilled from the crude oil with superheated steam at atmospheric pressure.

The distillate has the following characteristics :—

| | | | |
|---|---|---|---|
| Specific gravity at 60° F. | .. | .. | 0·9395 |
| Viscosity at 70° F. | .. | .. | 1090 secs. (Redwood) |
| 140° F. | .. | .. | 105 secs. |

Fifteen hundred cc. of the distillate oil were agitated with 150 cc. of acetone-sulphur dioxide, and afterwards allowed to settle. Seven

successive quantities of 150 cc. each of the solvent were employed, the extracts and the residual oil at each stage being separately examined. The solvent was removed from the extracts by evaporation, aided by a current of air passing over the surface, and from the residual oil by water washing and subsequent drying.

| Treatment. | Quantity of oil before treatment. c.c. | Per cent. of extract. | Specific gravity of residual oil at 60° F. | Colour of residual oil (Lovibond ¼ in. cell.). | Oxidation test of residual oil. |
|---|---|---|---|---|---|
| 1 .. | 1500 .. | 2·1 .. | 0·936 .. | 24 Yellow/2·5 Red .. | 2·00 |
| 2 .. | 1300 .. | 1·9 .. | 0·9345 .. | 20 „ /1·5 „ .. | 1·70 |
| 3 .. | 1100 .. | 2·7 .. | 0·9315 .. | 19 „ /1·5 „ .. | 1·25 |
| 4 .. | 900 .. | 2·7 .. | 0·9285 .. | 15 „ /1·2 „ .. | 1·05 |
| 5 .. | 700 .. | 2·7 .. | 0·9255 .. | 12 „ /1·2 „ .. | 0·65 |
| 6 .. | 500 .. | 4·9 .. | 0·9205 .. | 10 „ /1·0 „ .. | 0·55 |
| 7 .. | 300 .. | 6·6 .. | 0·9125 .. | 7 „ /0·7 „ .. | 0·35 |

Ultimate analyses of the residual oils and extracts gave the following results :—

| No. of Sample. | Residual oils. | | | | | Extracts. | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | C. | H. | N. | S. | O. | C. | H. | N. | S. | O. |
| 1 | 87·3 | 11·75 | 0·1 | 0·35 | 0·5 | 88·4 | 8·8 | 1·0 | 0·6 | 1·2 |
| 2 | 87·25 | 11·8 | 0·1 | 0·35 | 0·5 | 89·1 | 8·8 | 0·5 | 0·6 | 1·0 |
| 3 | 87·2 | 11·9 | 0·1 | 0·3 | 0·5 | 89·1 | 8·9 | 0·3 | 0·55 | 1·15 |
| 4 | 87·4 | 12·0 | 0·05 | 0·3 | 0·25 | 89·3 | 9·1 | 0·25 | 0·5 | 0·85 |
| 5 | 87·45 | 12·1 | 0·05 | 0·25 | 0·15 | 89·3 | 9·3 | 0·2 | 0·5 | 0·7 |
| 6 | 87·4 | 12·2 | 0·05 | 0·2 | 0·15 | 89·5 | 9·5 | 0·1 | 0·45 | 0·45 |
| 7 | 87·4 | 12·4 | 0·05 | 0·2 | nil | 89·7 | 9·6 | 0·1 | 0·5 | 0·1 |

The following table shows the change of viscosity of the oils at each stage :—

| Oil. | | Viscosity (Redwood—secs.). | | | |
|---|---|---|---|---|---|
| | | 70° F. | 100° | 120° | 140° |
| Original oil .. | .. .. | 1022 .. | 317 .. | 178 .. | 106·5 |
| Residual oil 1 | .. .. | 950 .. | 300 .. | 169 .. | 103·5 |
| 2 | .. .. | 919 .. | 291 .. | 167 .. | 100 |
| 3 | .. .. | 864 .. | 282 .. | 158 .. | 97·5 |
| 4 | .. .. | 835 .. | 268 .. | 158 .. | 96 |
| 5 | .. .. | 725 .. | 246 .. | 145 .. | 92 |
| 6 | .. .. | 674 .. | 236 .. | 138·5 .. | 87·5 |
| 7 | .. .. | 594 .. | 216 .. | 127 .. | 82 |

Molecular weights of two only of the oils were determined, viz., Residual Oil 4 and Extracted Oil 4. These were respectively 366 and 313. All molecular weights in this work were determined by the depression of the freezing-point of naphthalene.

The facts indicated by these results may be enumerated :—

(1) The oil has been divided into two portions (extracts and residual oils) of greatly different hydrogen content. As the final

extract and residue are quite dissimilar, it is obvious that but for exhaustion of material the series could have been extended, so producing a residue of hydrogen content well above 12·4 per cent.

The aggregate separation actually obtained represents :—

24 per cent. extracts averaging 9·3 per cent. hydrogen.
76 per cent. residual oils averaging 12·0 per cent. hydrogen.

But a better separation would have, of course, been effected if portions had not been withdrawn at each stage for analysis, etc.

(2) Oxygen and nitrogen compounds are concentrated in the extracted oils.

(3) Disregarding the nitrogen, sulphur and oxygen contents (the form of combination being unknown), the calculated representative formulæ for Residual Oil 4 and Extracted Oil 4 are, respectively :—

$$C_{27}H_{44}(C_nH_{2n-10}) \text{ and}$$
$$C_{24}H_{30}(C_nH_{2n-18}).$$

The Extracted Oil 4 fraction may be taken as approximately representative of the whole extract, being a middle fraction, but the residual oil is obviously a mixture, and the separation not having been carried to finality the final residual oil still contains, as has already been pointed out, a good proportion of extractable compounds. A portion of higher hydrogen content therefore approaches saturation much more closely than is indicated by the series formula shown above.

(4) The chemical stability of the oil, as indicated by the oxidation test, is increased progressively as the unsaturated portion is extracted. On the other hand, the viscosity is lowered substantially at each stage, but the slope of the viscosity-temperature curve progressively decreases. This is in accord with the fact that the extracted oil is exceedingly viscous at normal temperatures, and very rapidly loses viscosity as the temperature rises.

The second portion of the investigation described in this Part involved considerably more difficulty than exists in dealing with a distillate fraction. It was first necessary to remove from the crude oil all gasoline, kerosene and gas oil, without subjecting the oil to a temperature at which there would be a risk of decomposing it or otherwise modifying its molecular constitution.

A number of unsuccessful attempts to remove the crude oil constituents of lower boiling points than lubricating oils included (1) various attempts at fractional solution, and (2) attempts to cause sufficient evaporation without application of heat. It became evident that the petrol, kerosene and intermediate oil must be distilled off, the temperature being kept at a minimum. It proved to be possible to distil 75 per cent. of the crude, i.e. the whole of the gasoline, kerosene and gas oil, without allowing the temperature of

the oil to rise above 210° C., and only towards the end was the temperature above 200° C.

The crude oil was placed in a still of 5-gallons working capacity, but a full charge was not taken as the procedure contemplated was exceptional. When the distilling temperature reached 110° the pressure was gradually reduced to an ultimate minimum of 3 in., and steam was admitted when the still-head temperature was at 120° C. The quantity of steam was increased until, in the latter part of the distillation the volume of steam was many times that of the oil.

| Fraction. | Still-head temperature ° C. | Still temperature ° C. | Per cent. of crude oil (fractions). | Per cent. of crude oil (Cumulative). |
|---|---|---|---|---|
| 1 | — | — | 14·19 | 14·19 |
| 2 | 112 | 170 | 13·52 | 27·71 |
| 3 | 125 | 180 | 10·62 | 38·33 |
| 4 | 138 | 188 | 12·84 | 51·17 |
| 5 | 146 | 196 | 10·40 | 61·57 |
| 6 | 145 | 196 | 7·03 | 68·60 |
| 7 | 146 | 204 | 3·52 | 72·12 |
| 8 | 148 | 210 | 3·33 | 75·45 |

It will be seen that the temperature of the oil in the still did not rise above 210° C. While it is not absolutely certain that at this temperature no change whatever had taken place in the constitution of the oil, it is reasonable to assume that any such change would be quite small. It is of significance that a determination of asphalt in the residual oil gave a zero result, whereas if the same crude oil is distilled to a small residuum carefully under normal conditions with steam and under reduced pressure with no trace of cracked products being found the residuum is a pitch.

The second problem was the elimination of the paraffin wax, which constituted so large a proportion of the residue that the latter was a solid mass when cold, and the paraffin could not be separated by the usual methods. Ultimately the following procedure was tried and found to overcome the difficulty.

The oil-paraffin mixture was melted and added to a quantity of ignited bauxite (10-60 mesh) the latter being completely soaked by the oil. The mixture when cool was broken up, and was then found to be in such a condition that the whole could be agitated with a solvent while cold with good results. The solvent used was, as before, a solution of sulphur dioxide in acetone.

After eight extractions with the latter, the volume in each case being equal to that of the oil, the bauxite was dried and a second series of nine extractions made with ether-alcohol mixture (1:1). The liquid was filtered or siphoned off, cooled to $-10°$ C. or below, and again filtered from the flocculent precipitate of solid paraffins,

which were returned to the bauxite and residuum mixture. In both series of extractions the extracted oil was freed from solvent by evaporation under vacuum on the water bath, with a subsequent rapid passage of a current of air over the surface of the extract to remove the last traces of solvent.

The second series of extractions being completed, the bauxite and wax mixture, now practically free from oil, was freed from solvent by distillation on the water bath, and then placed in hot water. The melted wax was thus detached from the bauxite and was collected and weighed.

The bauxite was again dried and extracted with chloroform, which dissolved the resinous substances which had been adsorbed by the bauxite. These also were freed from solvent and weighed.

The following are the quantities of the various fractions obtained :—

Acetone-Sulphur Dioxide Extracts.

| No. | Per cent. by weight of residuum. | Description. |
|---|---|---|
| AS 1 | 10·3 | Dark oil of high viscosity. |
| AS 2 | 9·4 | |
| AS 3 | 5·4 | |
| AS 4 | 4·0 | |
| AS 5 | 3·1 | |
| AS 6 | 2·7 | Contain wax. |
| AS 7 | 1·9 | |
| AS 8 | 2·0 | |
| | 38·8 | |

Ether-Alcohol Extracts.

| No. | Per cent. by weight of residuum. | Description. |
|---|---|---|
| EA 1 | 0·9 | Mobile red oil. |
| EA 2 | 2·9 | |
| EA 3 | 1·2 | |
| EA 4 | 3·8 | |
| EA 5 | 2·0 | |
| EA 6 | 4·1 | |
| EA 7 | 2·0 | Contains little wax. |
| EA 8 | 1·9 | Contain wax. |
| EA 9 | 0·7 | |
| | 19·5 | |

Totals :—

| | |
|---|---|
| Acetone-sulphur dioxide extracts | 38·8 |
| Ether-alcohol extracts | 19·5 |
| Solid paraffin | 24·8 |
| Chloroform extract (resins, etc.) | 7·1 |
| Loss | 9·8 |
| | 100·0 |

A substantial loss is inevitable in work involving several transferences of material, but a considerable proportion is in this case due to a breakage which occurred during the ether-alcohol extraction (EA 5) in the process of distillation of the solvent.

### *Analysis of Fractions.*

Preliminary representative analyses of extract fractions resulted as follows :—

| No. | Average molecular weight. | Carbon % | Hydrogen. % | Sulphur % | Nitrogen. % | Oxygen % (by diff.). | Series formula calculated from C. and H. only. |
|---|---|---|---|---|---|---|---|
| AS 1 .. | 360 | 88·7 | 9·8 | 0·4 | 0·35 | 0·75 | $C_nH_{2n-10}$ |
| AS 4 .. | 380 | 87·7 | 10·8 | 0·4 | 0·3 | 0·8 | $C_nH_{2n-14}$ |
| AS 6 .. | — | — | — | 0·3 | — | — | — |
| AS 7 .. | — | 87·2 | 12·6 | — | — | — | — |
| AS 8 .. | 410 | 87·1 | 12·6 | 0·2 | — | — | $C_nH_{2n-2}$ |
| EA 1 .. | — | 86·0 | 13·5 | — | — | — | $C_nH_{2n-4}$ |
| EA 2 .. | 430 | — | — | — | — | — | — |
| EA 6 .. | 480 | 86·1 | 13·7 | — | — | — | $C_nH_{2n-4}$ |
| EA 9 .. | 395 | 86·1 | 13·7 | — | — | — | $C_nH_{2n-2}$ |
| Wax .. | 450 | 85·2 | 14·6 | nil | — | — | $C_nH_{2n+2}$ ($C_{32}H_{66}$) |
| Chloroform extract . | 430 | — | — | 0·1 | — | — | — |

A marked difference is evident between the two series of extracted oils. The composition of the more saturated series remains fairly constant throughout the series, the hydrogen content being only slightly influenced by the increasing proportion of wax, but in the acetone-sulphur dioxide series of extracts the hydrogen content increases to a marked extent. This change is partially due to an increasing wax content but it is also caused by an actual change in the character of the extracted oil.

The molecular weights and series formulæ are, of course, "average" and regard has not been paid to other elements than carbon and hydrogen in calculating the series formulæ, as it is not known how these other elements are combined in the compounds of which they form part.

The low molecular weight of EA9 may be due to the presence of wax, which in this case is soft and presumably of low molecular weight.

The wax residue is quite hard, dark in colour, and melts at 135° F.

For further examination of the extracted oils, fractions EA1—6 were united, as were fractions AS 1—5. These mixtures were practically free from wax, and may be regarded as representing the "saturated" and "unsaturated" (for want of better terms) portions of the lubricating oil.

The following were the results obtained :—

1. *Elementary Composition.*

| Oil. | Per cent. of total extracted oils. | Molecular wt. | Carbon. % | Hydrogen. % | Nitrogen. % | Oxygen by diff. % | Sulphur. % | Average Series Formula. |
|---|---|---|---|---|---|---|---|---|
| FA (Saturated).. | 25·8 | 450 | 86·2 | 13·5 | 0·2 | 0·05 | 0·05 | $C_nH_{2n-4}$ ($C_{31}H_{66}$) |
| AS (Unsaturated) | 55·1 | 380 | 88·5 | 10·25 | 0·3 | 0·6 | 0·35 | $C_nH_{2n-10}$ ($C_{28}H_{66}$) |

2. *Specific Gravity at 60° F.*

| | |
|---|---|
| Saturated oil .. .. .. .. .. .. .. .. | 0·890 |
| Unsaturated oil .. .. .. .. .. .. .. .. | 1·020 |

3. *Viscosity.*

The viscosity of the two fractions was determined at a number of temperatures, using Ostwald Viscometers, and the results calculated to Redwood Seconds.

| Temperature ° F. | Viscosity in Redwood Seconds. Saturated oil. | Unsaturated oil. |
|---|---|---|
| 70 .. | 926 .. | — |
| 100 .. | 346 .. | — |
| 120 .. | 205 .. | 2453 |
| 140 .. | 129 .. | 992 |
| 180 .. | 71 .. | 248 |
| 200 .. | 54 .. | 142 |

4. *Chemical Stability.*

The comparative instability of the unsaturated extract was quite evident, as it deposited asphaltic matter while standing untouched, although, as already stated, the residuum after topping gave no precipitate of asphalts. The asphalt content of the unsaturated oil (I.P.T. method) after standing for a few weeks was found to be 0·9 per cent.

The contrast of the behaviour of the two oils on heating to 120° C. was quite notable. In each 3 grams of oil were heated in an oven to the temperature stated, while contained in a flat silica dish.

| Oil. | Total Heating Time Hours. | Per cent. loss in weight. | Appearance of oil after heating. | Asphalt Per Cent. |
|---|---|---|---|---|
| Unsaturated — .. .. | — .. | — | 0·9 |
| „ .. 2 .. | 5·7 .. | On cooling set to asphaltic solid. | — |
| „ .. 6 .. | 14·3 .. | „ „ | 5·0 |
| Saturated .. 2 .. | 2·7 .. | No apparent change; possible slight darkening. | — |
| „ .. 6 .. | 6·0 .. | „ „ | nil |

*Oxidation Test.*—In view of the heavy precipitate of asphalt produced from the unsaturated oil it was futile to seek to determine

its oxidation value, but this test was carried out on the more saturated fraction.

Saturated Fraction Oxidation Value, 0·37 per cent.

*Conradson Coking Value.*—The following values were obtained :—

| | |
|---|---|
| Saturated oil .. .. .. .. .. .. | 1·37 |
| Unsaturated oil .. .. .. .. .. | 6·2 |
| Residual wax.. .. .. .. .. .. | 0·73 |

The value obtained from the saturated oil is unexpectedly high. A definite explanation of this is at present wanting, but it may be pointed out that the oil represents the "saturated" portion of the whole range of the higher liquid hydrocarbons, and therefore probably contains compounds of higher molecular weight than ordinarily.

**Discussion of Results.**

The outstanding feature of the analyses is the similarity of the unsaturated portion of the two oils, crude and distillate :—

| | Molecular weight. | Carbon. | Hydrogen. | Oxygen. | Nitrogen. | Sulphur. | Series formula. |
|---|---|---|---|---|---|---|---|
| Unsaturated oil from residual oil from crude .. | 380 | 88·5 | 10·25 | 0·6 | 0·3 | 0·35 | $C_nH_{2n-18}$ ($C_{28}H_{38}$) |
| Unsaturated oil from distillate .. | 313 | 89·3 | 9·1 | 0·85 | 0·25 | 0·5 | $C_nH_{2n-14}$ ($C_{14}H_{20}$) |

These results afford strong evidence that the oil which has been twice distilled, the first time under ordinary refinery conditions, has not been materially altered in constitution.

The oils are shown to contain two (or more) series of widely different composition. The unsaturated portion has the merit of high viscosity, but lacks stability. It may be noted that the latter, although highly unstable when isolated, has a good degree of stability when in admixture with a predominant portion of the comparatively saturated oil. Apart from the degree of stability at an elevated temperature, the relative lubricating value of "saturated" and "unsaturated" fractions remains to be established. Experimental enquiry on this subject is in progress.

The separated wax, which was not subjected to any process of purification, is shown to consist practically entirely of paraffins, with an average formula $C_{22}H_{46}$, but some wax of lower boiling point was included with the gas oil.

Finally, it has been shown that this petroleum contains no asphalt after having been reduced to a residuum of lubricating oils and paraffin wax, the distillation temperature having been raised to a maximum of 210° C., whereas when the crude is distilled to a small residuum under normal conditions, without cracking, the residuum consists of pitch.

## Part III.—On the Composition of the Lubricating Oil Constituents of Hardstoft Crude Oil.

The Crude Oil of Hardstoft is of special interest, among other reasons because of the low density of all its fractions, compared with the corresponding fractions of almost all other oils, and because of its large content of lubricating oil of high viscosity.

A residual lubricating oil—in this case a cylinder stock—was prepared by the method described in Part II. The last runnings of distillate were of the viscosity of a light spindle oil (42 seconds Redwood at 140° F.), and the residual oil amounted to 33·3 per cent. of the crude oil. It was not found possible in this instance to maintain the oil during the later part of the distillation at so low a temperature as in the other distillation, but the results gave no reason to suppose that the resulting residuum was affected by the somewhat higher temperature conditions.

| Fraction. | Still-head temperature. ° C. | Still temperature. ° C. | Per cent. of crude oil (fractions). | Per cent. of crude oil (cumulative). |
|---|---|---|---|---|
| 1 | 106 | 168 | 14·4 | 14·4 |
| 2 | 123 | 178 | 17·4 | 31·8 |
| 3 | 100 | 200 | 6·0 | 37·8 |
| 4 | 120 | 198 | 6·6 | 44·4 |
| 5 | 124 | 200 | 7·1 | 51·5 |
| 6 | 135 | 216 | 3·6 | 55·1 |
| 7 | 142 | 226 | 3·0 | 58·1 |
| 8 | 126 | 246 | 5·0 | 63·1 |
| Loss | — | — | 3·6 | 66·7 |
| Residuum | — | — | 33·3 | 100·0 |
| | | | 100·0 | |

The character of the residuum is represented by the following determinations:—

| | | |
|---|---|---|
| Specific gravity at 60° F. | | 0·8895 |
| Viscosity (Redwood) at 100° F. | | 1503 |
| | 140° | 465 |
| | 200° | 130 |
| Average molecular weight | | 690 |
| Hard asphalt | | nil |
| Ultimate analysis: Carbon | | 85·8 |
| Hydrogen | | 13·5 |
| Sulphur | | 0·7 |
| Nitrogen | | nil |
| Oxygen | | nil |
| | | 100·0 |

The crude oil contains a small quantity of paraffin. Part of the latter was distilled over, and the residuum appeared to contain a further small proportion. The separation of this paraffin was attempted, but unsuccessfully, as its solubility in the usual solvents differs but little from that of the oil. The quantity present was,

however, considered to be too small to have any material effect upon the results.

A portion of the residuum (400 c.c.) was extracted repeatedly with acetone-sulphur dioxide (800 c.c. each time), until the composition of the extract was almost the same as that of the residual oil. This involved six extractions, with a total extraction of 8 per cent. As the later extracts consisted largely of "saturated" oil the actual content of "unsaturated" oil is possibly below 8 per cent.

The following were the results of analysis :—

| Fraction. | Carbon. % | Hydrogen. % | Nitrogen. % | Sulphur. % | Oxygen. % | Average molecular weight. | Average series formula. |
|---|---|---|---|---|---|---|---|
| Extract No. 1 .. | 86·2 | 11·7 | 0·25 | 1·4 | 0·45 | 400 | $C_nH_{2n-12}$ ($C_{34}H_{56}$) |
| " " 6 .. | 85·8 | 13·3 | — | — | — | — | — |
| Residual oil .. | 85·6 | 13·7 | nil | 0·7 | nil | 725 | $C_nH_{2n-4}$ ($C_{52}H_{100}$) |

Further examination of the residual oil resulted as follows :—

| | |
|---|---|
| Specific gravity at 60° F. .. .. .. .. | 0·882 |
| Viscosity (Redwood) at 100° F. .. .. .. | 1647 secs. |
| 120° .. .. .. | 875 |
| 140° .. .. .. | 500 |
| 180° .. .. .. | 206 |
| 200° .. .. .. | 141 |

Heat Test (at 120° C.).

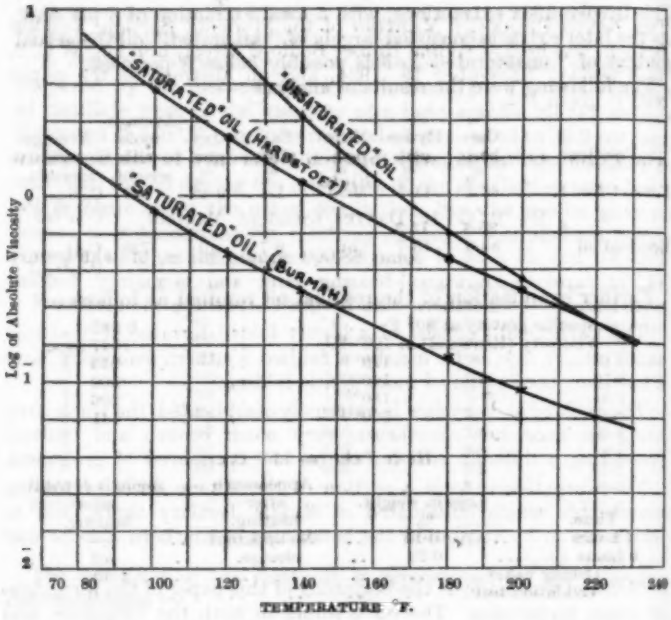
| Time. | Loss in weight. % | Appearance after heating. | Asphalt content after heating. |
|---|---|---|---|
| 2 hours .. | 0·16 .. | No apparent .. | — |
| 6 hours .. | 0·29 .. | change. .. | nil |
| Coking value .. .. | | .. .. .. | 1·39 |
| Oxidation test .. .. | | .. .. .. | nil |

## Discussion of Results.

Hardstoft lubricating oil consists essentially of hydrocarbons of a high degree of saturation and of high molecular weight. The average series formula of these hydrocarbons, $C_nH_{2n-4}$, is the same as that found by Mabery (*Ind. and Eng. Chem.*, 15, 1233; this *Journal*, 9, 427) in Cabin Creek (West Virginia) lubricating oil, and by the present authors to constitute a large proportion of the Burmah petroleum residuum examined by them (Part II.). It is notable, however, that Mabery found no lubricating oil constituents of so high a degree of saturation in the four other oils which he examined, including one (Rosenburg) representative Pennsylvania oil.

The similarity of the two residual oils obtained by the authors is further demonstrated by the respective curves obtained by plotting

the logarithm of absolute viscosity against temperature. The two curves are seen to be practically parallel within the range of temperatures 70°—200° F. The corresponding curve of one of the extract oils ($C_nH_{2n-18}$) is shown for comparison.




The zero value obtained in the oxidation test of the residual oil is quite extraordinary, and indicates that hydrocarbons of this type are practically without susceptibility to the action of oxygen. (The oxidation value obtained for the corresponding oil described in Part II. was 0·37 per cent.; the separation of the series was probably less complete.)

The authors desire to express their thanks to The Burmah Oil Co., Ltd., for permission to publish this series of papers. They are indebted also to Mr. H. T. Parker for valuable assistance in carrying out the work.

## STUDENTS' SECTION, LONDON BRANCH.

THE NINTH ORDINARY MEETING of the Students' Section, London Branch, was held at Aldine House, Bedford Street, London, W.C. 2, on Tuesday, November 18, 1924, and an abstract of the paper read is given below :—

### The Polish Oilfields, with Special Reference to the Boryslaw Field.

By T. G. B. DAVIES (Student Member).

POLAND has an area of some 88,000 square miles, of which only 41,250 acres is known oil-bearing land and is mainly concentrated along the northern side of the Carpathian mountains.

The Carpathians consist of a highly folded terraine of Mesozoic and Tertiary age, with usually a faulted southern boundary, and a northern borderland of more gentle folding.

The geology at Boryslaw is extremely complicated, the whole area being an enormous overthrust, very much broken and faulted, presenting a difficult area for the most experienced of geologists.

The Carpathians form a section of the Alpine series of folding movements which culminated in Middle Tertiary times, and to which are to be attributed the mountains of southern Europe and northern Africa.

Mention was made at the beginning of this paper of the formation of these mountains. The oil is found in both the Oligocene and Eocene strata, it being most abundant in the former at Boryslaw.

*Historical.*—The oil industry in Poland dates back as far as 1856 ; the production at that time was very small, the oil being obtained from shallow pits. In 1882 the Canadian Pole Tool rig was introduced, and this greatly increased the output.

In 1909 Poland seems to have had its maximum production, namely, 14,932,000 barrels, and ever since then has steadily decreased. During the war the output was very low, owing to the occupation of the wells by foreign armies, a great number of wells being destroyed and much damage done to the machinery.

The opening-up of new fields is essential, for at Boryslaw the conditions are not at all promising. One of two new areas have been tried and have yielded nothing but salt water, this being discouraging, as these particular areas were only half-a-mile away from producing wells.

*Methods of Drilling.*—So far as is known Poland is the only country in the world where gas, oil, and paraffin wax (ozokerite) are each separately worked, all these being found in or near Boryslaw.

The ozokerite is mined in a similar manner to coal, but the working conditions are far more dangerous. Natural gas is sometimes found issuing from the ground, and seepages of oil are occasionally met with.

Various methods of drilling are in use, the most important being the Cable, the Canadian Pole Tool, and the Rotary.

The Canadian Pole Tool rig is the oldest and still most popular rig in use, and is suited to the peculiar formations through which one has to drill in the Carpathians. At Boryslaw, where there are some 950 wells, 930 have been drilled by this method. An average well at Boryslaw takes five years to drill, the depth being about 4000 to 5000 ft. This is explained by the time lost in pulling up the bit. The poles or rods of steel, which are about 15 ft. long, have to be unscrewed one at a time, when hoisting the bit, and when lowering, each pole has to be screwed on again.

The inside of a Polish rig looks very bare and uninteresting, there being few tools, which are easily handled by one man. Three men are employed, a driller, helper and tower man. The driller controls the engine and drilling operations, while the tower man stands half way up the rig and, as the tools are pulled out, unscrews them from the hoisting rope. There are one or two spare drilling bits, a bailer, sinker bars, jars and spare rods. Hence on a Canadian rig far fewer tools, materials and accessories are necessary than on an American rig. The derrick is about 70 ft. high, and is covered with tin sheeting.

The next method now being used on some Polish fields is the American standard cable rig. The great advantage this system has over the Polish method lies in its rapid drilling progress, and an American rig will do in two and a half years what it takes a Canadian rig five years to do. One great drawback to the American rig, as used in Poland, is the under-reamer.

The third system, the Rotary, is comparatively new in Poland, but so far this system has not proved very satisfactory in Boryslaw. Its chief advantage is rapidity of drilling, and economy in casing. Considerable skill is necessary in judging the correct amount of pressure to be applied on the drilling stem in different degrees of hardness of rocks.

*Crude Oil.*—There are two distinctive kinds of crude oil in Poland, that found at Boryslaw, containing paraffin wax, and a low percentage of benzine, and the special type of oil which contains no

paraffin wax, and a higher percentage of benzine. At Bitkow, there is a crude oil found which contains over 50 per cent. benzine. Of the total production of Poland, about 75 per cent. is "standard Boryslaw" and 25 per cent. "special."

Mr. B. Dashkevitch asked whether the crude oil obtained at Bitkow could not be used in an unrefined condition?

Mr. H. G. Austin gave the audience an interesting account of the reasons why the American drillers were not a success.

Mr. Hull asked if the oil produced in Poland and Central Europe was consumed in the countries of production, and if so where were the refineries situated?

The Author, in reply, said he had seen benzine (crude) obtained from Bitkow, which was almost clear, and that it had actually been used in a motor car.

Poland's consumption is rather more than her production. Refineries are situated at Drohobycz and are capable of dealing with the Boryslaw oil; other refineries are situated in Czecho-Slovakia.

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## STUDENTS' SECTION, LONDON BRANCH.

The Tenth Ordinary Meeting of the Students' Section, London Branch, was held at Aldine House, Bedford Street, London, W.C. 2, on Tuesday evening, December 9, 1924.

Mr. R. F. Owen took the chair, and called upon Mr. Kay to read his paper, an abstract of which follows:—

### Some Legal Aspects of Petroleum

By J. B. Kay (Student Member).

The legal aspects of petroleum cover such a wide ground that it has been necessary to limit the scope of this paper to one particular phase of the subject, *i.e.*, oil leases.

The right to prospect land or to drill a well may be obtained in three ways:—

(*a*) By purchase of the land.
(*b*) By purchase of the oil and gas rights.
(*c*) By lease of the oil and gas rights.

When the land can be purchased at only a slight advance over the price of the oil and gas rights it should be.

The advantage in owning the oil and gas rights over leasing the rights is that one is not hastened into drilling prematurely.

As the third method is probably the one most universally adopted, it is important to bear in mind the aims of the law relating to leasing of public lands. The objects of such leasing laws are :—

(*a*) To fix a minimum area which shall constitute a separate lease.

(*b*) To impose a rate of royalty and decide what form it shall take.

(*c*) To define the minimum drilling obligations or alternatively the maximum annual payments.

(*d*) To impose reasonable conditions safeguarding property from injurious treatment or wasteful development.

The question of royalties demands more detail. The royalty, either net or gross, may be payable in kind or in value, usually the latter when it may be as a percentage, or on a predetermined quantity or as a valuation per unit of weight or volume. Sometimes the rate increases by steps, termed the progressive method. The degressive method deducts the rate by steps and so keeps the well economically productive for a longer time. The disadvantage of either plan is the lack of adjustment to maintenance cost, since the change might come long before or after the time when income equals outlay. A better method is to avoid all sudden changes by providing that all production less than a certain amount per week has one rate of royalty, oil produced in excess of that amount paying additional royalty.

## United States of America.

Until 1909 the leasing of lands was governed by the Placer Law of 1872, but this was found unsuitable for petroleum finding, and in 1909 the rights for leasing land were withdrawn until the passage of the 1920 Bill.

*The Mineral Leasing Law of* 1920.—The law applies to finds of petroleum, natural gas, oil-shale, coal, phosphate and saline deposits, and prospecting permits are issued to any citizen of the United States or to any corporation with the majority of stock held by United States citizens. The area under the permit is 4 square miles (2,560 acres) or less, for a period of two years. The permit cannot be granted within the geologic structure of an oilfield under production. The area must be rectangular, not less than $2\frac{1}{2}$ times wide as long: drilling is to commence within six months of issue of permit.

The following conditions are imposed.

At the end of the first year one well must be drilled to a depth of at least 500 ft., the diameter of hole not less than 6 in.

At the end of the second year one well must be drilled to a depth of at least 2,000 ft. unless oil or gas occurs earlier.

Twenty per cent. of the gross value of production is to be paid to the Government until the lease of the land is granted.

Upon discovery of oil, the owner of the permit is entitled to a lease of one quarter of the land included within the permit, or for at least 160 acres, on a 5 per cent. royalty.

Known productive lands prior to the 1920 Law, and areas proved productive since 1920 and not covered by prospecting permits, may be leased at not less than 12 per cent. royalty, or at an annual rental of 1 dollar per acre as long as the land is unproductive.

Tracts not greater than 640 acres (1 square mile) may be leased by public auction. The lease is gained by the bidder who offers the largest bonus as well as the fixed royalty or rental.

Under the Mining Law of Texas, 1913, the minimum area allowed for oil and gas exploitation is 1,280 acres (2 square miles) and no area greater than 200 acres is allowed within 10 miles of a producing and operating well.

If oil or gas is found in paying quantities, the operator must take out a lease before removing any, which lease may run for 10 years, costing annually 2 dollars per acre, payable in advance. In addition, a royalty of 12½ per cent. of the gross value of oil sold and 10 per cent. of the gross value of gas, is demanded by the State.

In *Wyoming* supposed oil-bearing State lands are leased for five-year periods at an annual rate of 16 dollars per acre with an obligation to work the area. A royalty of 10 per cent. of the gross value of the oil production is imposed.

*New Mexico* charges a minimum annual rental of 25 dollars per quarter section of 160 acres and a minimum royalty of 5 per cent. of the gross production value, for the first five years only.

The oil and gas exploitation rights of *Oklahoma* are sold to the highest bidder at public auction. For five-year leases no offer less than 12½ per cent. royalty as well as bonus is contemplated.

The rentals charged for leasing of the *Indian Reserve Lands* vary from 15 cents to 70 cents per acre. The *Osage Tribal Lands* are offered for auction with an increasing scale of annual rentals. For the first year the rental is 15 cents per acre, the second year it is 30 cents per acre, the third year it is 50 cents per acre, and for the fourth and succeeding years it is 1 dollar per acre. Royalties are fixed at 16⅔ per cent. (⅙) on gross value of production.

*South America.*—In most of the South American Republics the old Spanish mining laws are mainly intact.

Annual prospecting rights may be obtained in *Peru* at 30 soles (£3) for 4 hectares (10 acres). Under the law of 1909, which is to remain

unaltered for twenty-five years, no royalties are payable on production "as long as the product of the property is treated and sold in the country." Petroleum is classified with mineral deposits which may account for the reservation of payment of royalty.

Under the 1906 law of *Bolivia* all oil and gas is the exclusive property of the State. No royalties of any kind are collected by the Government or can be demanded by surface-owners. Since 1912 a temporary abeyance of certain laws has been made for five years, during which time no fees are payable for oil leases of maximum area of 64 hectares.

*Mexico*, by the law of 1883, until 1917, and *Columbia* place the entire ownership of oil and gas rights with the landlord. If other than the surface owners desire to work the deposits, the filing of claims and consent of the owner is necessary. In Mexico since 1917, during the Carranza régime, the law was altered. All mineral and oil rights are the property of the Government, but leasing arrangements made with landlords under the old laws are still valid.

In *Venezuela*, by the 1915 law, oil is placed in the third class of deposits classified in the mining law. Rights to work oil deposits can only be obtained by direct negotiation with the President of the Republic. A concession may be granted for a specified term at an agreed royalty, or a rental, or both. Since 1922 the law has been reframed. All oil and gas rights belong to the State. A three-year prospecting licence is granted (for a definite area) which may be of any shape. At the end of the period, half the area may be retained for development, the remainder reverting to the State.

*Argentina.*—Prospecting permits are necessary, obtainable free of charge from the Government and from the soil owner. Exclusive prospecting rights are only obtainable by written application to the local authorities. The mining laws are being reframed.

*Europe.*—Up to 1916 prospecting licences were granted in *Russia* termed "zaiavka," issued in unproven areas, for one or two years at an annual charge of 5 roubles per dessiatine (3s. 7d. per acre) on units of 37½ dessiatines (100 acres). From this area, a smaller area of 10 dessiatines (27 acres) could be selected, and a lease termed an "otvod" taken out if oil were found. Previous to the issue of this "otvod" evidence of research and discovery was necessary.

The annual rental for the first ten years was 10 roubles per dessiatine (7s. 5d. per acre); for the next ten years 100 roubles per dessiatine, the rental being multiplied by ten at the end of each ten-year interval.

In *Rumania* the oil and gas rights belong to the surface owner and usually are based for twenty-nine years for a royalty or rent, sometimes both, and even for a lump sum.

The "Ten Year Law" of Rumania, passed in 1914, provided that no oil leases might be left undeveloped for ten years.

The "Consolidation Law" of Rumania provides that the registration of the title of a land in the court of law establishes a good title.

*Canada.*—The Dominion Government of Canada has jurisdiction only over the unappropriated "crown" lands of Manitoba, Saskatchewan, Alberta, and North West Territory, the Yukon Territory and certain areas of British Columbia. Separate laws are in force for the provincial governments of British Columbia, New Brunswick, Ontario and Quebec.

Exploitation of Dominion oil and gas lands is only open to citizens of Canada or to corporations having principal places of business in Canada.

The Canadian leasing laws are not dissimilar to those of other British possessions which are to be mentioned. The high cost of prospecting licences, however, detracts from extensive work.

In undeveloped and partially undeveloped British possessions (Burmah, Trinidad, Egypt) two types of licences are issued. First, there is the short-termed exploration licence for a general survey and geological examination. Secondly, there is the prospecting licence over less-extended areas with definite obligations. Discovery of oil entails the application for a development lease before the removal of any oil.

*Egypt*, by the Mining Law of 1916, allows a prospecting area, rectangular in shape, no side of which is more than 2 kilometres in length. A prospecting licence is granted for a year with two renewals of equal length, at the option of the Department of Mines, at a fee of £25 annually. Until a lease is taken out, no realisation on the value of the product is permitted. The fee for the licence is £2 10s. per hectare per annum, and a royalty of 7½ per cent. on the gross value of production.

Similar conditions prevail in *Burmah*, where a royalty of 6d. per 40 gallons of oil produced, is imposed. The Yenangyaung Field of *Upper Burmah* is imposed by an ancient custom incorporated in hereditary rights of a native colony, the Twinzas. The local estate owner may offer a bonus of free oil rights over certain areas of his land for prospecting purposes as long as he owns the rights over well-sites inscribed by a 60-foot diameter circle, enclosing thereby an area of 31·5 square yards.

As far as South America is concerned, it appears that all the Republics are open to British development except, perhaps, where the local governments grant concessions.

The oilfields of Rumania offer no hindrance to the British subject.

It is with the United States of America that the greatest difficulty occurs. Since the States are the largest producers it is as well to examine the comparative limitations between them and the British Empire as regards oilfield development.

The American will say that in Great Britain, the Government and the Oil Monopolies are more or less united, and that American oil interests operate independently of the State. Before lands may be leased in the United States, the operator must be a United States citizen, or have an intention of becoming a United States citizen, or if a corporation is desirous of operating, the majority of stock must be held by United States citizens.

With the discovery of oil in the Pyrenees, the laws of France demand some notice. Concessions may be granted with the reservation that the company wishing to operate, has the majority of stock held by French capital.

Mr. R. F. Owen wished to know what were the laws affecting petroleum in the United Kingdom.

Mr. H. G. Austin asked whether, in any of the States of America, the surface owner possessed the petroleum rights. He suggested that Mr. Kay would do well to take some of the other phases of the legal aspects of petroleum, for subjects for future papers.

Mr. H. S. Garlick said he would like to know the present legal conditions governing Persia.

Mr. Ashley Carter said he would like to add to Mr. Kay's reference to the Twinzas and the Yenangyaung Field. As a personal experience he had seen the location of a hand-dug well within twenty feet of an oil rig.

Mr. E. Clark wished to know what was meant by "net production." Also, what was the object of limiting the area of the lease: would it not make for economic production to have large areas, rather than many small competitive plots? Finally, he would like to know some of the main clauses of the 1922 Petroleum Law of Venezuela, and whether the 1916 laws of Russia were still in force.

Mr. J. O. Tanner asked what was the position of foreigners, in British protectorates, who wished to develop oil property.

Mr. H. R. Lovely desired to know whether oil-shale was governed by the same laws as petroleum.

In reply, Mr. Kay said that under the old Mining Law of the United Kingdom, only gold and silver belonged to the Crown, the remainder of the mineral rights being in the possession of the

soil-owner. Petroleum had not been considered, but since finds of petroleum were known, a difficult problem has arisen. Was the Crown entitled to the rights, due to the omission from the Mining Law, or did the rights automatically belong to the landlord?

In answer to Mr. Austin's query, by the 1920 Mineral Leasing Law of the United States, all oil and gas rights belonged to the State.

The author was unable to give the laws governing Persia, other than that it was under the law governing all other British possessions.

By "net production" was meant the actual amount of oil available after the crude had been refined, and was ready for the market, as opposed to "gross production," which was the actual amount of oil raised from the well. By limiting the leasing area, monopolising of a district by one company was prevented, which was easily accomplished under the 1872 Placer Law of the States. The author was unable to give a detailed account of the 1922 Venezuela Petroleum Law, other than what was given in the paper. Also, his references on Russia only extended to 1916, so that he was unable to state whether the 1916 Russian Laws were still in operation.

In any British protectorate or possession, only British subjects could work oil properties. However, it was possible, and is being done at the present time, for foreigners to finance English companies working in the British Empire.

Oil-shales and natural gas were included with petroleum in all Petroleum Laws.

*References.*

Van Wagenen, "International Mining Law."
J. Thompson, "Petroleum Laws of all America."
Johnson and Huntley, "Oil and Gas Production."
A. B. Thompson, "Oilfield Development."
L. C. Uren, "Petroleum Production Engineering."

## New Development in the Turner Valley Oil Field, Alberta.*

By R. T. Elworthy.

The Turner Valley field, sometimes known as the Black Diamond or Okotoks field, is the only field in Western Canada where oil has, as yet, been produced in commercial quantity, though shipments have recently been reported to have been contracted for from the Wainwright field. It is situated in the foothills of the Rocky Mountains, about forty miles south-west of Calgary.

Oil of a very light character was first found in 1914, and though the hope of proving the area to be a large oil field was not realised, there has been since 1916 a small production of light oil, amounting on an average to about ten thousand barrels a year.

At the present time only one well yields oil, but several wells give large flows of natural gas from which two or three pints of gasoline per thousand cubic feet can be extracted. Two absorption plants produce yearly about 400,000 Imperial gallons of gasoline. The gas after treatment is piped to Calgary to supplement the supply from the Bow Island and Foremost fields.

On account of the alternation of hard and soft beds in the strata in this area, and the steepness of their dips, drilling is very difficult, and trouble has been experienced in almost every one of the twenty or thirty wells drilled during the last ten years.

The progress made by the Royalite Company, a subsidiary of the Imperial Oil Company, in deepening one of its wells during the last year has therefore been followed with great interest.

No. 4 Royalite well, commenced in 1922, had been drilled to a depth of 3185 ft., and during the winter of 1923–4 yielded over six million cub. ft. of gas a day. In the summer of 1924 drilling was continued, and, at 3450 ft., the hole penetrated a limestone formation. As greater depth was attained the limestone became more porous, and at 3740 ft., a tremendous flow of gas of over twenty-one million cub. ft. a day was opened up. By this the drilling tools were lifted three hundred feet in the hole, causing them to jam in the casing. A fishing string was also lost.

After the well had blown open for a few days, a valve was fitted and the gas closed in. In less than half-an-hour the pressure had risen to over twelve hundred pounds, and before the pressure could be relieved the 6-inch and 8-inch casings were lifted to the crown block of the derrick, causing considerable damage. A week or two

* Canadian Official Mining News Letter, No. 47.

later, and before repairs were made, the well again blew in, and on this occasion the gas caught fire, probably ignited by sparks caused by small stones striking the metal parts of the rig. After burning fiercely for eleven days the fire was eventually put out by means of steam from seven boilers.

The work of getting the well under control was then successfully accomplished. It is probable that the gas from the well will be treated in the Royalite gasoline extraction plant to remove gasoline before it is piped to Calgary, although the large amount of sulphur compounds which it contains may prove a handicap. In addition to the large volume of wet gas given off, the well is reported to be making about three hundred barrels a day of light crude oil of about 70 degrees Baume gravity. If this flow is maintained it will prove the most productive well in the field. This discovery will undoubtedly stimulate great interest in this field, and it is probable that several new wells will be drilled in the near future.

## The Wainwright-Irma Oil and Gas Area, Alberta.*

By G. S. Hume.

East of the Rocky Mountain foothills area in the Province of Alberta the rock formation dips into a vast trough or syncline, over large areas of which the petroliferous Lower Cretaceous strata are believed to be beyond drilling depth. In the eastern and central part of the province, however, these strata rise much nearer to the surface, and over a large area of this district there is a regional south-westerly dip of a few feet only to the mile, resulting in the so-called terrace structure of this part of Alberta. The work of the Geological Survey has demonstrated that on this terrace there are a number of low folds with one of which the oil in the British Petroleums' wells is associated. The accumulation of oil and gas is evidently related to the folding, and it is hoped that drilling on folds other than those already tested will lead to the discovery of other oil-producing areas.

The results so far achieved by drilling show: (1) a large gas area in the vicinity of Viking from which gas is now being piped to Edmonton and other centres; (2) a gas area with possibilities of oil near Fabyan on a fold on which the Imperial (Fabyan) No. 1 and Maple Leaf No. 1 Wells have been drilled, and (3) a fold north of Wainwright, on which Nos. 2 and 4 British Petroleums' wells are located. The Imperial (Fabyan) No. 1 well has a daily capacity of about 10,000,000 cu. ft. of gas with some oil, and the Maple Leaf well, which has not penetrated the large gas sand of

* Canadian Official Mining News Letter, No. 55.

Imperial (Fabyan) No. 1 well, has a gas capacity of 2,500,000 cu. ft. from a higher sand. Below this gas sand in the Maple Leaf well an oil sand is reported to have been penetrated, but has not been tested. In any productive fold the gas, on account of its lightness, usually occurs at the crest with the oil further down the dip, and a water zone is generally found underneath the oil towards the flanks. If oil is present in the Fabyan fold in any quantity the most favourable location for drilling would be down the dip; such, in fact, is the location of the Maple Leaf well in its relation to the Imperial (Fabyan) No. 1. The Maple Leaf wells may thus be considered as a fair test of the oil possibilities of the Fabyan fold.

The British Petroleums' well No. 4 "came in" last autumn and flowed at the rate of about 25 barrels a day through a two inch tubing. The flow has now appreciably diminished and it is understood that the Company intends to install a pump to test the capacity of the well. The fold which occurs here is rather low, the dip of the strata being gentle on the south-west side, and about 40 feet in half a mile on the north-east side. Gas is not present in such large quantities as in the Fabyan fold further west, and consequently oil with some gas fills the crest of the fold. A water zone underlies the oil and this was reached in No. 2 British Petroleums' well, but has not been penetrated in the No. 4 well. No. 4 is, therefore, in a position to produce oil without encountering any immediate water troubles. The productive sand in No. 2 well was reported to have a thickness of 17 feet, but only about 10 or 11 feet of this was drilled in the No. 4 well.

The product of the British Petroleums' Nos. 2 and 4 wells is a heavy oil containing little or no gasoline in its original state, but with a good percentage of lubricants. No cracking tests have been made by the Department of Mines, but it is understood that a considerable percentage of gasoline can be obtained by this treatment. A carload of the oil has been delivered to the Canadian National Railways and tests will be made very soon regarding the possibilities of its use as a fuel for the locomotives of this Company.

## Discussion on "The Modern Rotary Drilling System."*

Replying to Mr. H. Pennington's communicated discussion, which has just been brought to my attention, Mr. L. R. McCollum writes:—

"I shall take up what appeals to me as the least important matter first—*i.e.*, the matter of using data which are common

* L. R. McCollum, *Jnl.* 41, pp. 1-26, Feb., 1924.
† *Jnl.* 46, pp. 826-827, Nov., 1924.

property throughout the oilfields of the world where the rotary system is in use. It did not occur to me that any of my audience would assume that I was giving data which I had obtained through research work of my own, because I thought I had made it plain that such knowledge as I possessed had been garnered through many years of work introducing the rotary system of drilling in both the eastern and western hemispheres. If my paper overlapped an article of Mr. Pennington's it was merely in a matter of discussing methods, the knowledge of which is common property to all men interested in this system of drilling, and it did not occur to me to give him credit any more than I would have credited the dictionary for the correct spelling of a word.

During the past twelve months I have spent most of my time in the oilfields of the United States, making a thorough investigation of the more recent developments in oilfield practices, visiting, among other places, both California and Texas, and it is gratifying to me to know that the paper which I had the honour of reading before your Institution twelve months ago, would be in every essential point an accurate description of the methods in vogue to-day.

Realising that the members of your Institution were interested in the development of the rotary and not in American geography or in our little sectional jealousies, I laid particular stress upon the work done in California because, in my judgment, that is where the rotary has attained its greatest efficiency, and where it was developed from what was known as the "small Texas outfit" to the heavy California type rotary.

With reference to Mr. Pennington's remarks on the expense of taking continuous cores, the question of the necessity of taking continuous cores or occasional cores was thoroughly discussed in the paper and subsequent rebuttal articles.

Unfortunately I must plead guilty to ignorance on the subject of his automatic core taking device. I have never heard of it. One wonders how it is possible to take cores at will and remove them with a sand line through six inch drill-pipes, which we must assume are equipped with six-inch tool joints having the usual two and a-half inch openings. If he does not advocate the use of such tool joints for the drilling of commercial oil wells, he is retrograding ten to fifteen years. It is evident that Mr. Pennington is discussing a strictly coring apparatus, perhaps something on the order of a Sullivan or similar diamond drill, which is not in any sense an economical or commercial oil well drilling rig.

Last month I visited a location in Texas where a well-known core taking device was being operated on a contract basis for one of the largest British owned oil companies in the United States. Operations had been proceeding for over a year and had reached a

depth of 2,260 feet. The contract called for the completion of a well to a depth of 3,000 feet with a diameter large enough to make a commercial well in the event the oil strata was encountered. At the time of my visit the drillers were introducing 5-3/16 inch casing, which means that in the event they encounter an oil strata it will be necessary to introduce a casing of smaller diameter to shut off water properly, and a still smaller diameter casing through which oil can be produced. It was frankly admitted that this endeavour had ceased to be a commercial proposition, and it was intimated that the loss in this contract would be in the neighbourhood of 40,000 dollars. As geological research in an unproved territory, it might justify the expenditure. But such research work was not the subject of my paper.

## Discussion on "Somerset Oil Shales."*

The following contributions have been received :—

### From Mr. Walter J. Cooper :—

The remarks relative to the Lias deposits adjoining the Bristol Channel are very accurate. The local limestone, though much jointed, usually makes a safe and good roof, especially the beds towards the base of the Lias. The Lias carries abundance of water, and mining operations in it are, on this account, difficult and troublesome.

The South Wales Oil Shales do not constitute a commercial proposition from an oil recovery point of view. The yields are generally low—often below 1 per cent., and the maximum I have ever found was 9 per cent. (i.e., about 22 gallons per ton). With oil at present prices, I also regard the Somerset Oil Shales as an unprofitable investment, as, except from the beach exposures, they will be very costly to get. My attention was first drawn to the South Wales deposits in 1891 ; in fact, I think I am the original discoverer. In that year I distilled samples of the shale in our Laboratory and obtained an oil which was mobile and pale brown in colour, possessed an excessively fœtid odour and burned with a white, very smoky flame, giving a smell not unlike burning caoutchouc. On page 876 of the paper 9 in. shale should read 6 in. "Clod." This material immediately underlies the 6 in. "Shoddy," and varies from 6 in. to 9 in. in thickness.

It is doubtful if heating to 950° C. for seven minutes would expel all the $CO_2$. The sulphur would be best estimated by oxidation

* Shatwell, Nash, and Graham, Jnl. 47, pp. 872-883. Dec. 1924.

with chromic acid or by aqua regia mixed with bromine. The ignition method usually gives too low a result, as some of the sulphur escapes.

The spent Somerset shales would be practically valueless for cement making, owing to their high sulphur content. For that reason we do not here use the 6 in. Clod.

Analyses of the 6in. "Shoddy" and 6in. "Clod" are given below.

*Analyses of South Wales Lias Beds.*

| | A. 6 in. Clod. Per cent. | B. 6 in. Shoddy. Per cent. |
|---|---|---|
| Specific gravity | 2·341 | 2·618 |
| Calcium carbonate | 55·89 | 86·96 |
| Magnesia | 2·47 | 1·08 |
| Silica | 18·42 | 5·90 |
| Alumina | 5·20 | 2·40 |
| Iron oxide | 1·98 | 0·54 |
| Calcium sulphate | 0·47 | 0·25 |
| Ferric sulphide (pyrites) | 3·58 | 0·75 |
| Moisture | 0·75 | — |
| Combined water and organic matter, $CO_2$ of $MgCO_3$ | 10·38 | 2·30 |
| Alkalies | not estimated | not estimated |
| | 100·18 | 99·14 |

*Notes.*

A. The carbonate of lime varies from 40 to 60 per cent. All the lime is present as carbonate or sulphate.

The magnesia is to a large extent combined other than as carbonate, but the separation was not made.

The maximum yield of oil from this shale was about 9 per cent., which is considerably above the average. In the sample in question, it would be about 6 or not over 7 per cent.

The carbonate of lime varies from 80 to 93 per cent. All the lime is present as carbonate or sulphate.

The magnesia is nearly all present as carbonate, but a little is present in some other form.

The analyses add up high. The error is probably in the volatile matter (other than $CO_2$), which was abnormal.

Both samples A and B were averages of the beds exposed at the time the analyses were made.

The 6 in. "Shoddy" is very fossiliferous (mostly Ostrea Liassica), whilst the shale below is practically non-fossiliferous.

From **Mr. R. H. Findlater**:—

In the discussion of the paper by Shatwell, Nash, and Graham on "Somerset Oil Shales," the Chairman expressed the opinion that proximate analyses are of no value in judging of the quality of an

oil shale. With this view the present writer is not in entire agreement. Certainly no chemist intimately associated with the shale oil industry would accept the percentage of volatile matter obtained in the proximate analysis of an oil shale as a measure of the quantity of oil that might be expected on distillation; indeed, proximate analyses are never performed in shale works laboratories in the routine testing of shale for oil yield. When a new material is being examined, however, a proximate analysis is not without a certain significance. It is a readily performed operation which gives an approximate idea of the total volatile matter, fixed carbon, and ash. A knowledge of the percentage of fixed carbon and of ash is of importance in practical retorting; it indicates, in low temperature retorting, how much carbonaceous residue will find its way to the waste heap, and in retorting by the Young and Beilby process approximately how much carbon is available for conversion into gas of the water gas type. It is, of course, well known that in the case of a shale with a high sulphur content, a proximate analysis may not give even an approximate idea of the carbon content; but in such cases the residue from a determination of volatile matter, by heating the shale in a crucible covered with its lid (the usual method of proximate analysis) can be used for the determination of sulphur in the ash plus carbon by Eschka's method. And, further, a determination of the sulphur in the ash can be made by the same method. Having made these two determinations the percentage of sulphur associated with the carbon can readily be calculated.

# REVIEWS.

BITUMINOUS SUBSTANCES (SCIENTIFIC PROGRESS OF PRACTICAL IMPORTANCE DURING THE LAST 15 YEARS). By P. E. Spielmann, with a Foreword by J. Kewley. (London: Ernest Benn, Ltd., 1925. Pp. 206 + xvi.)

The historical survey (in which we seem to recognise fragments of H. G. Wells's "Outlines of History") with which this little book opens is as entrancing as a romance. It is with interest one finds quotations from ancient inscriptions such as these: "Nebuchadnezzar, King of Babylon, he who made Esaglia and Esida glorious . . . has made a road glistening with asphalt and burnt bricks . . . (&) a mighty superstructure of shining dust (&) made them strong within with bitument. . . ."

It is no far cry from this episode to the laying of the Thames Embankment. Herodotus again (B.C. 450) described the production of pitch from the island of Zante and refers to a well near Susa which was yielding asphalt, salt and oil, whilst in more recent times Sir John Mandeville (A.D. 1356) wrote: ". . . the water of the Dead Sea is right bitter and this water casteth out a thing that men call Aspatum. . . ."

The author's practical experience of asphalt as a paving material and his work on the Standardisation Committee of the Institution of Petroleum Technologists put him in an excellent position to speak authoritatively of bituminous materials. From the standpoint of theory the lamentable ignorance of contemporary chemists and physicists not only of the constitution, but also of the properties of the multifarious substances classified as asphalts can merely be indicated as an unfortunate fact and it cannot be said that Dr. Spielmann goes very far in elucidating the structure of these substances. Indeed, a more critical examination of the rather sparse evidence he has collated would be of advantage.

There are some annoying lapses which should have been eradicated during proof reading; on p. 18 occurs the term "evaporisated"; on p. 21, "ten per cent. of Aluminium Chloride dissolves in petroleum and on distillation gives a light fraction"; on p. 25, "Bergin's" for Bergius'; on p. 35, solubility instead of insolubility; on p. 37 "a series of experiments confirm one another"; on p. 43, "the pathological, crumbling . . . depends on the decolloidification"; and on p. 48, "surface tension—this rather elusive property."

The author should have known (p. 84) that it was certainly not Herschel who discovered that logarithms of viscosity are additive.

Perhaps the most irritating sample of the author's journalese appears on p. 86, "that state of arbitrariness that pervades this whole subject resulting in this case from the lack of purity of phenomenon."

It is most unfortunate that this book is so handicapped by the author's egregious English, because an honest attempt has been made to indicate promising lines of research and to map out for the investigator those regions where, something, at any rate, has been cleared. A. E. D.

THE SUBJECT INDEX TO PERIODICALS, 1921. K. Science and Technology. Pp. 251. London: The Library Association. December, 1924. £1 1s. net.

This bibliography of articles on scientific and technical subjects published in periodicals during 1921 is exceedingly well indexed under a multiplicity of subjects, a noteworthy feature being the cross indexing. It is to be regretted that the interval between the date of reference (1921) and the

date of publication (1924) is so long, and one would like to see the index for subsequent years published with a shorter lapse of time if possible.

To anyone desiring to trace references to a particular subject the work will be extremely useful and should find a place on the bookshelves of all scientists and technologists. G. S.

CHEMICAL ENGINEERING AND CHEMICAL CATALOGUE. Edited by D. M. Newitt, Ph.D., B.Sc., etc. Pp. 200. London: Leonard Hill, 1925.

The use of chemicals and chemical plant in industrial undertakings is continually increasing, and this work presents a catalogue of chemicals, machinery, etc., cross indexed to enable prospective purchasers to trace quickly the manufacturers of the particular commodity or plant they may require.

The first part, about 100 pages, is occupied by the Index to Commodities, and gives names and addresses of manufacturing firms, followed by 125 pages of catalogue matter in which various firms describe and illustrate their products. The remaining 24 pages contain the B.E.S.A. specification for steam-jacketed pans, specification for filter plates and frames, and an index setting out chemicals and plant used in various industries.

The Index to Commodities appears to be capable of considerable expansion in future editions as regards the names of firms, particularly with reference to mineral oil suppliers and oil plant manufacturers.

The book should prove of considerable usefulness to all users of chemicals and chemical plant. G. S.